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Fifty-eighth Edition.—121st Thousand.

BY CHAS. H. HASWELL,

RINE, AND MECHANICAL ENGINEER, MEMBER OF THE AM. SOC. OF CIVIL ENGINEERS, OF THE
UTIONS OF CIVIL ENGINEERS, AND OF NAVAL ARCHITECTS, ENGLAND, OF THE ENGINEERS'
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An examination of facts is the foundation of science.

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BY CHAS. H. HASWELL,

Civil, Marine, and Mechanical Engineer, M. Am. Soc. C. E. and Ins'n of C. E.

MENSURATION.

For Tuition and Reference, containing Tables of Weights and Measures; Mensuration of Surfaces, Lines, and Solids, and Conic Sections, Centres of Gravity, &c. To which is added, Tables of the Areas of Circular Segments, Sines of a Circle, Circular and Semi-elliptical Arcs, &c. By CHAS. H. HASWELL, Civil and Marine Engineer, &c. Sixth Edition. 12mo, Sheep, 90 cents.

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INSCRIBED

TO

CAPTAIN JOHN ERICSSON, LL.D.,

AS A SLIGHT TRIBUTE TO HIS GENIUS AND ATTAINMENTS,
AND IN TESTIMONY OF THE SINCERE REGARD
AND ESTEEM OF HIS FRIEND,

THE AUTHOR.

PREFACE

To the Forty-fifth Edition.

THE First Edition of this work, consisting of 284 pages, was submitted to the Mechanics and Engineers of the United States by one of their number in 1843, who designed it for a convenient reference to Rules, Results, and Tables connected with the discharge of their various duties.

The Twenty-first Edition was published in 1867, consisted of 664 pages, and, in addition to the original design of the work, it was essayed to embrace some general information upon Mechanical and Physical subjects.

The Tables of Areas and Circumferences of Circles have been extended, and together with those of Weights of Metals, Balls, Tubes, Pipes, etc., of this and some preceding editions were computed and verified by the author.

This edition is a revision and an entire reconstruction of all preceding, embracing amended and much new matter, as Masonry, Strength of Girders, Floor Beams, Logarithms, etc., etc.

To the young Mechanic and Engineer it is recommended to cultivate a knowledge of Physical Laws and to note results of observations and of practice, without which eminence in his profession can never be attained; and if this work shall assist him in the attainment of these objects, one great purpose of the author will be well accomplished.

NOTE 1.—*Mechanical and Physical subjects, commencing at p.* 427 *and ending at p.* 870, *are given in alphabetical order.*

2.—*Tons are given and computed at* 2240 *lbs.*

3.—*Degrees of temperature are given by the Scale of Fahrenheit.*

INDEX.

A

ADDENDUM.

NOTE.—Tons are given and computed at 2240 lbs.

Degrees of temperature are given by the Scale of Fahrenheit.

EXPLANATIONS OF CHARACTERS AND SYMBOLS

Used in Formulas, Computations, etc., etc.

$=$ *Equal to*, signifies equality; as 12 inches $=$ 1 foot, or $8 \times 8 = 16 \times 4$.

$+$ *Plus*, or *More*, signifies addition; as $4 + 6 + 5 = 15$.

$-$ *Minus*, or *Less*, signifies subtraction; as $15 - 5 = 10$.

$\times$ *Multiplied by*, or *Into*, signifies multiplication; as $8 \times 9 = 72$. $a \times c$ $a \, . \, d$, or ad, also signify that a is to be multiplied by d.

$\div$ *Divided by*, signifies division; as $72 \div 9 = 8$.

: *Is to*, :: *So is*, : *To*, signifies *Proportion*, as $2 : 4 :: 8 : 16$; that is, as 2 i *to* 4, *so is* 8 *to* 16.

$\therefore$ signifies *Therefore* or *Hence*, and $\because$ *Because*.

——— *Vinculum*, or *Bar*, signifies that numbers, etc., over which it i placed, are to be taken together; as $\overline{8 - 2 + 6} = 12$, or $3 \times \overline{5 + 3} = 24$.

. *Decimal point*, signifies, when prefixed to a number, that that numbe has some power of 10 for its denominator; as .1 is $\frac{1}{10}$, .15 is $\frac{15}{100}$, etc.

$\backsim$ *Difference*, signifies, when placed between two quantities, that thei difference is to be taken, it being unknown which is greater.

$\surd$ *Radical sign*, which, prefixed to any number or symbol, signifies tha *square root* of that number, etc., is required; as $\sqrt{9}$, or $\sqrt{a+b}$. The degre of the root is indicated by number placed over the sign, which is terme *index* of the *root* or *radical*; as $\sqrt[3]{\ }$, $\sqrt[4]{\ }$, etc.

$>$ ⅂, $<$ ⌊, signify *Inequality*, or *greater*, or *less than*, and are put betwee two quantities; as a ⅂ b reads a greater than b, and a ⌊ b reads a less than l

() [ ] *Parentheses* and *Brackets* signify that all figures, etc., within ther are to be operated upon as if they were only one; thus, $(3 + 2) \times 5 = 25$ $[8 - 2] \times 5 = 30$.

$\pm$ $\mp$ signify that the formula is to be adapted to two distinct cases, a $c \mp v = a$, either diminished or increased by v. Here there are expresse two values: first, the difference between c and v; second, the sum of c and v

In this and like expressions, the upper symbol takes preference of the lower.

p or π is used to express ratio of circumference of a circle to its diamete $= 3.1416$; $\frac{1}{4} p = .7854$, and $\frac{1}{6} p = .5236$.

$^{\circ}$ $'$ $''$ $'''$ signify *Degrees*, *Minutes*, *Seconds*, and *Thirds*.

$'$ $''$ set *superior* to a figure or figures, signify, in denoting dimensions, *Fee* and *Inches*.

a' a'' a''' signify a *prime*, a *second*, a *third*, etc.

$_1$, $_2$, added to or set *inferior* to a symbol, reads *sub* 1 or *sub* 2, and is use to designate corresponding values of the same element, as h, h_1, h_2, etc.

^{2}, ^{3}, ^{4}, added or set *superior* to a number or symbol, signify that that num ber, etc., is to be *squared*, *cubed*, *etc.*; *thus*, 4^2 means that 4 is to be mul plied by 4; 4^3, *that it is to be cubed*, as $4^3 = 4 \times 4 \times 4 = 64$. The pou or *number of times a number is to be* multiplied by itself, is shown by *number added, as* ^{2}, ^{3}, ^{4}, ^{5}, *etc.*

NATIONS OF CHARACTERS AND SYMBOLS

Used in Formulas, Computations, etc., etc.

ignifies equality; as 12 inches = 1 foot, or $8 \times 8 = 16 \times 4$.

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r set *superior* to a number or symbol, signify th *squared, cubed*, etc.; thus, 4^2 means that *that it is to be cubed*, as $4^3 = 4 \times 4 \times 4 =$ *es a number is to be* multiplied by itself *2, 3, 4, 5, etc.*

ILLUSTRATION.—When a number, hyp. log. of which = a given figure or number, is required.

Multiply figure or number (hyp. log.) by .434 294 (modulus of com. log.) = com. log. of figure.

Thus, Required the number, hyp. log. of which = .02. $.02 \times .434\,294 = .00\,868\,588$, com. log., and 1.0202 = *number*.

Log. $100^{.059} = .059 \times$ log. of $100 = .059 \times 2 = .118$; the number corresponding to log. .118, is 1.3122; hence, $100^{.059} = 1.3122$. That is, if 100 is raised to 59th power, and the 1000th root is extracted, the result will be 1.3122.

Differential and Integral Calculus.—*In Equation*, $u = 3x^2 - 2x$, u is termed a function of x. If it is desired to indicate the fact that u thus depends for its value upon value of x, without expressing exact value of u in terms of x, following notation is used:

$$u = f(x), \qquad u = F(x), \qquad \text{or } u = \phi(x).$$

Each of these notations is read, u is a function of x. If in such function of x value of x is assumed to commence with 0 and to increase uniformly, the notation indicating *rate* of increase is dx, and is read "the differential of x."

Differentiation. d is its symbol, and it is the process of ascertaining the ratio existing between the rate of increase or decrease of a function of a variable and the rate of increase or decrease of the variable itself. If $y = 3x^2$, y or its equal $3x^2$ is the function of x, and x is the independent variable, while the exponent of the variable or the primitive exponent is 2.

By the operation of Calculus, such expressions are differentiated by diminishing the exponent of the variable by unity, multiplying by the primitive exponent, and attaching the dx.

Hence, $dy = 2 \times 3x\,dx = 6x\,dx$. This indicates the relation between the differential of y, the function of x, and the differential of x itself.

Assume that x increasing at rate of 3 per second becomes 4; that is, $x = 4$, and $dx = 3$; hence $dy = 6 \times 4 \times 3 = 72$. That is, if x is increasing at rate of 3 per second, at the time that $x = 4$, the function itself is increasing at rate of 72 per second.

To differentiate an expression of two or more terms, it is necessary to differentiate them separately and connect the results with the signs with which the terms are connected.

Thus, differentiating $u = 3x^2 - 2x$, we have $du = d(3x^2 - 2x) = 6x\,dx - 2\,dx = (6x - 2)\,dx$.

Assuming $x = 4$ and $dx = 3$, we have $du = (6 \times 4 - 2) \times 3 = 66$. This indicates that when $x = 4$, and is increasing at rate of 3 per second, the function u, or $3x^2 - 2x$, is at same instant increasing at rate of 66 per second.

Integration. Its symbol $\int$ was originally letter S, initial of *sum*, the symbol of an operation the reverse of differentiation; and when the operation of integration is to be performed twice, thrice, or more times, it is written $\int\int$, $\int\int\int$, etc.

By the operation of Calculus, expressions are integrated by increasing the exponent of the variable by unity, dividing by the new exponent, and detaching the dx.

Hence, integrating the differential $6x\,dx$, we have $\int 6x\,dx = 3x^2$. This ult is the function, the differential of which is $6x\,dx$.

o integrate an expression of two or more terms, it is necessary to inte- the terms separately and connect the results with the signs with which ms a[illegible]ted.

[illegible]$-2)\,dx$, we have $\int(6x-2)\,dx = \int(6x\,dx - 2\,dx)$ ılt is the function the differential of which is $(6x$ dx.

the exponent 0, as x^0 or 3^0, is equal to unity.

The operation of summation may also be illustrated in use of the symbol $\int$. Assuming $x = 4$, the former of the preceding results becomes $\int 6x\,dx = 3x^2 = 48$, the latter $\int (6x - 2)\,dx = 3x^2 - 2x = 40$.

Here x is assumed to commence at 0 and to continue to increase by infinitely small increments of dx until it becomes 4. The summation is the addition of all these values of x from 0 to 4.

Arithmetically.—The first formula may be written

$6(x' + x'' + x''' + \text{etc.})\,dx$. If then x is to advance from 0 to 4 by increments of 1, we have $6\,(0 + 1 + 2 + 3 + 4) \times 1 = 60$, which exceeds 48. If dx is assumed to be .5, the result is 54. The correct result is obtained only when dx is taken infinitely small. By Arithmetic this is approximated, but it is reached by the operations of Calculus alone.

The second formula may be written

$(6[x' + x'' + x''' + \text{etc.}] - 2[x^{0'} + x^{0''} + x^{0'''} \text{ etc.}])\,dx$. Assuming $x = 4$, and $dx = 1$, we have $(6[1 + 2 + 3 + 4] - 2[1 + 1 + 1 + 1]) \times 1 = 52$, which exceeds 40. If $dx = .25$, the result would be 43, and if .125 it would be 41.5, ever approaching but never reaching 40, so long as a finite value is assigned to dx.

Δ, *Delta*, when put before a quantity, signifies an absolute and finite increment of that quantity, and not simply the rate of increase.

Σ, *Sigma*, signifies the summation of finite differences or quantities. Thus, $\Sigma y^2\,\Delta x = (y'^2 + y''^2 + y'''^2 + \text{etc.})\,\Delta x$. Assume $y' = 6$, $y'' = 8$, $y''' = 4$, and Δx the common increment of $x = 5$, then $\Sigma y^2\,\Delta x = (36 + 64 + 16) \times 5 = 580$.

NOTATION.

1 = I.	20 = XX.	1 000 = M, or CIƆ.
2 = II.	30 = XXX.	2 000 = MM.
3 = III.	40 = XL.	5 000 = $\overline{\text{V}}$, or IƆƆ.
4 = IV.	50 = L.	6 000 = $\overline{\text{VI}}$.
5 = V.	60 = LX.	10 000 = $\overline{\text{X}}$, or CCIƆƆ.
6 = VI.	70 = LXX.	50 000 = $\overline{\text{L}}$, or IƆƆƆ.
7 = VII.	80 = LXXX.	60 000 = $\overline{\text{LX}}$.
8 = VIII.	90 = XC.	100 000 = $\overline{\text{C}}$, or CCCIƆƆƆ.
9 = IX.	100 = C.	1 000 000 = $\overline{\text{M}}$, or CCCCIƆƆƆƆ.
10 = X.	500 = D, or IƆ.	2 000 000 = $\overline{\text{MM}}$.

As often as a character is repeated, so many times is its value repeated, as CC = 200.

A less character before a greater diminishes its value, as IV = V − I.

A less character after a greater increases its value, as XI = X + I.

For every Ɔ annexed to IƆ the sum as 500 is increased 10 times.

If C is placed on left side of I as many times as Ɔ is on the right, the number is doubled.

A bar, thus ¯, over any number, increases it 1000 times.

Illustration 1.—1880, MDCCCLXXX. 18 560, $\overline{\text{XVIII}}$DLX.

2.—IƆ = 500. CIƆ = 500 × 2 = 1000. IƆƆ = 500 × 10 = 5000. CCIƆƆ = *5000 × 2 = 10 000.* *IƆƆƆ* = 500 × 10 × 10 = 50 000. CCCIƆƆƆ *= 50 000 × 2 = 100 000.*

.HRONOLOGICAL ERAS AND CYCLES FOR 1892.

.892, *or the 117th year of the Independence of the United States of America,* *.sponds to*

.e year 7400–13 of the Byzantine Era;
" 6606 of the Julian Period;
" 5652–53 of the Jewish Era;
" 2668 of the Olympiads, or the last year of the 667th Olympiad, commencing in July (1892), the era of the Olympiads being placed at 775.5 years before Christ, or near the beginning of July of the 3938th year of the Julian Period;
" 2645 since the foundation of Rome, according to Varro;
" 2204 of the Grecian Era, or the Era of the Seleucidæ;
" 1608 of the Era of Diocletian.

The year 1310 of the Mohammedan Era, or the Era of the Hegira, begins on the 26th of July, 1892.

The first day of January of the year 1892 is the 2,412,101st day since the commencement of the Julian Period.

Dominical Letters..................C, B	Lunar Cycle or Golden Number..... 12
Epact............................ 1	Solar Cycle......................... 25

Roman Indiction was a period of 15 years, in use by the Romans. The precise time of its adoption is not known beyond the fact that the year 313 A.D. was a first year of a Cycle of Indiction.

Julian Period is a cycle of 7980 years, product of the Lunar and Solar Cycles and the Indiction (19 × 28 × 15), and it commences at 4714 years B.C.

6513 + (given year — 1800) = year of Julian Period, extending to 3267.

Note.—If year of Julian Period is divided by 19, 28, 15, or 32, the remainders will respectively give the *Lunar* and *Solar Cycles*, the *Indiction*, and the *Year of the Dionysian.*

MEASURES OF LENGTH.

Standard of measure is a brass scale 82 inches in length, and the yard is measured between the 27th and 63d inches of it, which, at temperature of 62°, is standard yard.

Lineal.

12 inches = 1 foot.
3 feet = 1 yard.
5.5 yards = 1 rod.
40 rods = 1 furlong.
8 furlongs = 1 mile.

Inches.	Feet.	Yards.	Rods.	Furl.
36 =	3.			
198 =	16.5 =	5.5.		
7920 =	660 =	220 =	40.	
63 360 =	5 280 =	1 760 =	320 =	8.

Inch is sometimes divided into 3 *barleycorns*, or 12 *lines*.
A hair's breadth is .020 83 (48th part) of an inch.
1 yard = .000 568, and 1 inch = .000 015 8 of a mile.

Gunter's Chain.

7.92 inches = 1 link. | 100 links = 1 chain, 4 rods, or 22 yards.
80 chains = 1 mile.

Ropes and Cables.

1 fathom = 6 feet. | 1 cable's length = 120 fathoms.

Geographical and Nautical.

..uming the Equatorial radius at 6 967 459.893 yards (3958.784
. U. S. Coast Survey, = 69.094 Statute miles.
..ds or 6080.27 feet.
..niles.

Log Lines.

mating a mile at 6080.27 feet, and using a 30″ glass,
knot = 50 feet 8.03 inches. | 1 fathom = 5 feet .08 inch.

28″ glass is used, and 8 divisions, then
knot = 47 feet 5 inches. | 1 fathom = 5 feet 11.25 inches.

ine should be about 150 fathoms long, having 10 fathoms between chip and ot for stray line.

—This estimate of a mile or knot is that of U. S. Coast Survey, assuming ial radius of Earth to be 6967459.893 yards and a Meter to be 39.370432 of the Troughton scale at 62°.

Cloth.

ail = 2.25 inches. | 1 quarter = 4 nails. | 5 quarters = 1 ell.

Pendulum.

6 points = 1 line. | 12 lines = 1 inch.

Shoemakers'.

is 4.125 inches, and every succeeding number is .333 of an inch. are 28 numbers or divisions, in two series or numbers—viz., from 1 nd 1 to 15.

Miscellaneous.

lines or 72 points = 1 inch. | 1 hand = 4 inches.
palm = 3 inches. | 1 span = 9 inches.
1 cubit = 18 inches.

Vernier Scale.

er Scale is $\frac{1}{10}$, divided into 10 equal parts; so that it divides a scale into 100ths when two lines of the two scales meet.

ric, by Act of Congress of July 28, 1866.

Measurement is the METER, *which by this Act is declared to be* 39.37 *ins.*

ominations.	Meters.	Inches.	Feet.	Yards.	Miles.
ter...........	.001	.0394	—	—	—
eter...........	.01	.3937	—	—	—
ter...........	.1	3.937	.328083	—	—
....	1.	39.37	3.28083	1.09361	—
eter...........	10.	393.7	32.80833	10.93611	—
eter...........	100.	—	328.08333	109.36111	—
ter...........	1000.	—	3280.83333	1093.61111	.62137
eter...........	10000.	—	—	—	6.2137

ic system, values of the base of each measure—viz., Meter, Liter, Stere, ramme—are decreased or increased by following prefix. Thus,

th part or .001. | Deci, 10th part or .1. | Hekto, 100 times value.
th " .01. | Deka, 10 times value. | Kilo, 1000 "
Myria, 10000 times value.

The Meter, as adopted by England, France, Belgium, Prussia, and Russia, termined by Capt. A. R. Clarke, R.E., F.R.S., 1866, which at 32° in terms al standard at 62° F. is 39.370432 *inches* or 1.09362311 *yards*, its legal by Metric Act of 1864 being 39.3708 *inches*, the same as adopted in

Kater's comparison, and the one formerly adopted by the U. S. Ord = 39.370797 1 *inches*, or 3.280899 76 *feet*, and the one adopted Survey, as above noted, is = 39.370432 35 *inches*.

Equivalent Values in Metric Denominations of U. S

Denominations.	Value in Meters.	Denominations.	Values in Meters.
Inch.............	.0254	Rod.............	5.029 209 9
Foot.............	.304 800 6	Furlong	201.168 396
Yard.............	.914 401 8	Mile.............	1609.347 168

Approximate Equivalents of Old and Metric U. S. Measures of Length.

1 Kilometer ....= .625 *mile.*	1 Chain .....= 20 *meters.*
1 Mile ....= 1.6 *kilometers.*	1 Furlong ...= 200 "
1 Pole or Perch .= 5 *meters.*	5 Furlongs ...= 1 *kilometer.*

1 Foot .... = 3 *decimeters* or 30 *centimeters.*
1 Metre ...... = 3.280 833 *feet* = 3 *feet* 3 *ins.* and 3 *eighths.*
11 Meters ..... = 12 *yards.* | 1 Decimeter ... = 4 *inches.*
1 Millimeter .. = 1 *thirty-second of an inch.*

To Convert Meters into Inches.—Multiply by 40; and *to Convert Inche into Meters.*—Divide by 40.

Approximate rule for Converting Meters or parts, into Yards.—Add on eleventh or .0909.

Inches Decimally = Millimeters.

Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.
.01	.25	.2	5.08	.48	12.2	.76	19.3	2	50.8
.02	.51	.22	5.59	.5	12.7	.78	19.8	3	76.2
.03	.76	.24	6.1	.52	13.2	.8	20.3	4	101.6
.04	1.02	.26	6.6	.54	13.7	.82	20.8	5	127
.05	1.27	.28	7.11	.56	14.2	.84	21.3	6	152.4
.06	1.52	.3	7.62	.58	14.7	.86	21.8	7	177.8
.07	1.78	.32	8.13	.6	15.2	.88	22.4	8	203.2
.08	2.03	.34	8.64	.62	15.7	.9	22.9	9	228.6
.09	2.29	.36	9.14	.64	16.3	.92	23.4	10	254
.1	2.54	.38	9.65	.66	16.8	.94	23.9	11	279.4
.12	3.05	.4	10.2	.68	17.3	.96	24.4	12	304.8
.14	3.56	.42	10.7	.7	17.8	.98	24.9	= 1 foot.	
.16	4.06	.44	11.2	.72	18.3	1.	25.4		
.18	4.57	.46	11.7	.74	18.8				

Inches in Fractions = Millimeters.

[illegible]ghths.	Six-[illegible]enths.	Thirty-seconds.	Milli-meters.	Eighths.	Six-teenths.	Thirty-seconds.	Milli-meters.	Eighths.	Six-teenths.	Thirty-seconds.	Milli-meters.	Eighths.	Six-teenths.	Thirty-seconds.	Milli-meters.
		1	.79			9	7.14			17	13.5			25	19.8
			1.59		5	—	7.94		9	—	14.3		13	—	20.6
			[illegible].38			11	8.73			19	15.1			27	21.4
			[illegible]17	3	—	—	9.52	5	—	—	15.9	7	—	—	22.2
			[illegible]97			13	10.32			21	16.7			29	23
			[illegible]76		7	—	11.11		11	—	17.5		15	—	23.8
			[illegible]6			15	11.91			23	18.3			31	24.6
						—	12 7	6	—	—	19	8	—	—	25.4

[illegible] equivalent values of inches and millimeters [illegible] centimeters, decimeters, and meters, may b[illegible] of decimal point.

[illegible]r, and remove decimal point successively by on[illegible] centimeter, decimeter, and meter become

Ins.	
[illegible]........ 3.94	.32 inch = 8.13 millimeters
[illegible]........ 39.4	3.2 inches = 81.3 "

MEASURES OF SURFACE.

ıches = 1 square foot. | 9 square feet = 1 square yard.
Irchitect's Measure, 100 square feet = 1 square.

Land.

		Yards.	Rods.	Roods.
ıre yards	= 1 square rod.	1210.		
.re rods	= 1 square rood.			
ıre roods / .re chains	= 1 acre.	4840 =	160.	
s	= 1 square mile.	3 097 600 =	102 400 =	2560.

feet, 69.570 109 yards square, or 220 by 198 feet square = 1 Acre.

Paper.

quire. | 20 quires = 1 ream. | 21.5 quires = 1 printer's ream.
ams = 1 bundle. | 5 bundles = 1 bale.

Drawing.

....	13 × 16 inches.	Columbier	23 × 34	inches.
....	15 × 20 "	Atlas	26 × 34	"
....	17 × 22 "	Theorem	28 × 34	"
....	19 × 23 "	Doub. Elephant,	27 × 40	"
l ...	19 × 27 "	Antiquarian ...	31 × 53	"
....	22 × 30 "	Emperor	40 × 60	"
....	23 × 28 "	Uncle Sam	48 × 120	"

Peerless .... 18 × 52 inches.

Tracing.

ı ..... 20 × 30 inches.	Grand Royal ...... 18 × 24 inches.
own .. 30 × 40 "	Grand Aigle ...... 27 × 40 "
Crown, 40 × 60 "	Vellum Writing, 18 to 28 ins. in width.

Mounted on cloth, 38 ins. in width.

Miscellaneous.

sheet = 4 pages.	1 duodecimo = 24 pages.
quarto = 8 "	1 eighteenmo = 36 "
octavo = 16 "	1 bundle = 2 reams.

1 piece wall-paper, 20 ins. by 12 yards.
1 " " " French, 4.5 sq. yards.
Roll of Parchment = 60 sheets.

Copying.

100 Words = 1 Folio.

by Act of Congress of July 28, 1866.

Unit of Surface is Are or Square Dekameter.

er (39.37^2) = 1549.9969 sq. ins., but by this Act is declared to be 1550 sq. ins.

ns.	Sq. Meters.	Sq. Inches.	Sq. Feet.	Sq. Yards.	Acres.
......	.0001	.155	—	—	—
......	.01	15.50	.107 638	—	.
}	1.	1550.	10.763 888	1.196	
......	100.	—	1076.388 88	119.6	
......	10000.	—	—	11 960.	

Equivalent Values in Metric Denominations of U. S.

Denominations.	Sq. Meters.	Denominations.	Sq. Meters.	Sq. Hectares.	Sq. Ares.
Sq. Inch.....	.000 645 16	Sq. Chain ...	404.686 47	—	4.046 865
" Foot.....	.092 903 23	" Rood....	1011.716 175	—	10.117 162
" Yard.....	.836 129 07	" Acre	4046.864 699	.404 686	40.468 647
" Rod......	25.292 904	" Mile.....	—	258.999 34	25 899.934 074

Approximate Equivalents of Old and Metric U. S. Square Measures.

6.5 square centimeters = 1 *sq. inch.*
1 " meter = 10.75 *sq. feet.*
1 acre = 1.16 per cent. over 4000 *sq. meters.*
1 square mile = 259 *hectares.*

MEASURES OF VOLUME.

Standard gallon measures 231 cube ins., and contains 8.338 882 2 avoirdupois pounds, or 58 373 Troy grains of distilled water, at temperature of its maximum density (39.1°), barometer at 30 ins.

Standard bushel is the *Winchester*, which contains 2150.42 cube ins., or 77.627 413 lbs. avoirdupois of distilled water at its maximum density. Its dimensions are 18.5 ins. diameter inside, 19.5 ins. outside, and 8 ins. deep; and when heaped, the cone must not be less than 6 ins. high, equal 2747.715 cube ins. for a true cone.

A struck bushel contains 1.244 45 cube feet.

Liquid.

	Cube Ins.	Gills. Pints.
4 gills = 1 pint.	28.875	
2 pints = 1 quart.	57.75	8.
4 quarts = 1 gallon.	231.	32 = 8.

Dry.

	Cube Ins.	Pints. Quarts. Galls.
2 pints = 1 quart.	67.2006	
4 quarts = 1 gallon.	268.8025	8.
2 gallons = 1 peck.	537.605	16 = 8.
4 pecks = 1 bushel.	2150.42	64 = 32 = 8.

Cube.

	Inches.
1728 cube inches = 1 foot.	
27 cube feet = 1 yard.	46656

NOTE.—A cube foot contains 2200 cylindrical inches, or 3300 spherical inches.

Fluid.

	Minims. Drams. Ounces.
60 minims = 1 dram.	
8 drams = 1 ounce.	480.
16 ounces = 1 pint.	7 680 = 128.
8 pints = 1 gallon.	61 240 = 1024 = 128.

Nautical.

lacement in salt water .... = 35 cube feet.
tered internal capacity .... = 40 " "

Dimensions of a Barrel.

r ins.; bung, 19 ins.; length, 28 ins.; volume, 7689 cube ins.

Miscellaneous.

1 cube foot	7.4805 gallons.
1 bushel	9.30918 gallons.
1 chaldron = 36 bushels, or	57.244 cube feet.
1 cord of wood	128 cube feet.
1 perch of stone	24.75 cube feet.

1 quarter = 8 bushels. | 1 load hay or straw = 36 trusses.

		Galls.
...l		32
...e		42
...Sherry	35×50	108
...Port	34×58	115
...Teneriffe		100
...Malaga	33×53	105

		Galls.
Puncheon of Scotch Whisky		110 to 130
Puncheon of Brandy	34×52	110 to 120
Puncheon of Rum		100 to 110
Hogshead of Brandy	28×40	55 to 60
Pipe of Madeira		92
Hogshead of Claret		46

...gshead is one half, a Quarter cask is one fourth, and an Octave is one eighth ...e, Butt, or Puncheon.

...etric, by Act of Congress of July 28, 1866.

Base of Measurement is a cube Decimeter or Liter, which is declared to be 61.022 *cube ins.*

Cube Measures.

...nominations.	Values.	Cube Inches.	Cube Feet.	Cube Yards.
...ntimeter	.001 cube milliliter	.061 022	—	—
...cimeter	1 cube liter	61.022	.035 313 657	—
...ter	Kiloliter or stere..	—	35.313 657	1.308

Dry Measures.

...ations.	Values.	Cube Ins.	Quarts.	Pecks.	Bushels.	Cube Yards.
...	1 cube centimeter.	.061	—	—	—	—
...r	10 " "	.6102	—	—	—	—
...	.1 " decimeter..	6.1022	—	—	—	—
...	1 " "	61.022	.908*	.1135	—	—
...r	10 " "	—	9.08	1.135	.28375	—
...r	.1 " meter	—	—	11.35	2.8375†	.1308
...	1 " "	—	—	—	28.375	1.308

* Or .227 *gallon.* † 3.5313657 *cube feet.*

—In practice, term cube Centimeter, abbreviated to cc, is used instead of ... and cube Meter instead of Kilometer.

...alent Values in Metric Denominations of U. S.

Dry Measures.

...nominations.	Centiliters.	Deciliters.	Liters.	Dekaliters.
...	—	—	—	—
...	—	—	—	—
...	—	.110125	1.10125	11.0125
...	—	.4405	4.405	44.05
...	.0881	.881	8.81	88.1
...	.3524	3.524	35.24	352.4

Liquid Measures.

...ations.	Liters.	Drams.	Ounces.	Pints.	Quarts.	Gallons.
...	.001	.27	—	—	—	—
...	.01	2.7	.338	—	—	—
...	.1	27	3.38	.211	-	—
...	1	—	33.8	2.11		.26417
...	10	—	—	21.1		
...	100	—	—	.		
...	1000	—	—	.		

Approximate Equivalents of Old and Metric U. S. Measures of Volume.

1 Gallon..........= 4.5 *liters.*	1 cube meter ....= 1.33 *cube yards.*
1 Liter...........= .26 *gallon.*	1 " yard...........= .75 " *meter.*
1 cube foot......= 28.3 *liters.*	1 " kiloliter = 2240 *lbs. nearly of water.*

MEASURES OF WEIGHT.

Standard avoirdupois pound is weight of 27.7015 cube inches of distilled water weighed in air, at (39.83°) barometer at 30 inches.

A cube inch of such water weighs 252.6937 grains.

Avoirdupois.

	Drams.	Ounces.	Pounds.
16 drams = 1 ounce.			
16 ounces = 1 pound.	256.		
112 pounds = 1 cwt.	28 672 =	1 792.	
20 cwt. = 1 ton.	573 440 =	35 840 =	2240.

1 pound = 14 *oz.* 11 *dwts.* 16 *grs.* Troy, or 7000 *grains.*
1 ounce = 18 *dwts.* 5.5 *grains* Troy, or 437.5 *grains.*
1 dram = 1 *dwt.* 3.343 75 *grains* Troy, or 53.5 *grains.*
1 stone = 14 *pounds.*

Troy.

	Grains.	Dwt.
24 grains = 1 dwt.		
20 dwt. = 1 ounce.	480.	
12 ounces = 1 pound.	5760 =	240.

7000 Troy grains = 1 lb. avoirdupois.
437.5 " " = 1 oz. "
27.343 75 Troy grains = 1 dram "
175 Troy pounds = 144 lbs. "
175 " ounces = 192 oz. "
1 " ounce = 480 grs. "
1 " pound = .822 857 lb.
1 avoirdupois pound = 1.215 278 *lbs. Troy.*

Apothecaries.

	Grains.	Scruples.	Drams.
20 grains = 1 scruple.			
3 scruples = 1 dram.	60.		
8 drams = 1 ounce.	480 =	24.	
12 ounces = 1 pound.	5760 =	288 =	96.

45 drops = 1 teaspoonful or a fluid dram.
2 tablespoonfuls = 1 ounce.

The pound, ounce, and grain are the same as in Troy weight.

Diamond.

1 grain = 16 parts.	4 grains = 3.2 Troy grains.
16 parts = .8 Troy grain.	1 carat = 4 grains.

15.5 carats = 1 Troy ounce.

Lead.

'der of lead = 8 pigs.
-6.5 to 7.5 feet in width and from 30 to 35 feet in length.

'ain.

ts per Bushel.

Lbs.		Lbs.		Lbs.
..... 56	Oats.....	32	Barley....	48

Miscellaneous.

COAL.

Anthracite		1 cube foot = 1.75 broken.
"		50 to 55 lbs. per cube foot.
"		41 to 45 cube feet = 1 ton broken.
Bituminous		70 to 78 lbs. per heaped bushel.
"		40 to 50 lbs. per cube foot.
"	Cumberland	53 " " " "
"	Cannel	50.3 lbs. per cube foot.
"	Welsh	43 cube feet = 1 ton.
"	Lancashire	44 " " = 1 "
"	Newcastle	45 " " = 1 "
"	Scotch	43 " " = 1 "
"	R. N. allowance	48 " " = 1 "
Charcoal, hardwood		18.5 lbs. per cube foot.
" pine wood		18 " " " "

WOOD.

ia pine . . 2700 lbs. = 1 cord. | Southern pine . 3300 lbs. = 1 cord.

EARTH.

nd . . 21 cube feet = 1 ton.	Marl or Clay, 28 cube feet = 1 ton.
gravel, 23 " " = 1 "	Mold . . . . 33 " " = 1 "

tric, by Act of Congress of July 28, 1866.

Veight is the GRAM, which is weight of one cube centimeter of pure water hed in vacuo at temperature of 4° C., or 39.2° F., which is about its temture of maximum density = 15.432 *grains.*

inations.	Values.	Grains.	Ounces.	Lbs.	Ton.
l	1 cube millimeter	—	—	—	—
a	10 " "	.154 32	—	—	—
	.1 " centimeter	1.543 2	—	—	—
	1 " "	15.432	.035 27	—	—
l	10 " "	—	.352 7	—	—
a	1 deciliter	—	3.527	.220 46	—
or Kilo	1 liter	—	35.27	2.204 6	—
a	10 "	—	—	22.046	—
	1 hektoliter	—	—	220.46	.098 419
Tonneau.	1 cube meter	—	—	2204.6	.984 196

a = 2.679 17 *lbs. Troy*, or 2 *lbs.* 8 *oz.* 3 *dwts.* .3072 *grain.*

lent Values in Metric Denominations of U. S.

inations.	Grams.	Dekagrams.	Denominations.	Grams.	Kilograms.
	.064 8	—	Ounce	28.3502	.028 35
	1.296	—	" Troy	31.1042	.031 1
ht	1.555 2	—	Pound	453.6028	.453 6
	1.771 87	17.7187	" Troy	373.2504	.373 25
oth.)	3.888	38.88	Ton	—	1016.057 28

ximate Equivalents of Old and New U. S. Measures of Weight.

and the gram are at nearly equal distances above and below the Thus,

. . = 1 016 057.28 grams. | 1 kilogram . .

1 nearly 15.5 *grains* (about .5 per cent. less
a *about 2.2 pounds* avoirdupois (about .25
grams, or a metric ton, nearly 1 Engl. ton (a

C

Electrical. (*British Association.*)

Resistance.—Unit of resistance is termed an *Ohm*, which represents resistance of a column of mercury of 1 sq. millimeter in section and 1.0486 meters in length, at temperature 0° C.

1 000 000 Microhms........ =	1 Ohm.	
1 Microhm......... =	1000 absolute electro-magnetic units.	
1 Ohm............. =	1 000 000 000	" " " "
1 000 000 Ohms............ =	1 Megohm or 10^{15}	" " " "

Electro-motive Force.—Unit of tension or difference of potentials is termed a *Volt.*

1 000 000 Microvolts.. =	1 Volt.
1 Volt........ =	100 000 000 absolute electro-magnetic units.
1 Megavolt ... =	1 000 000 Volts.

Current.—Unit of current is equal to 1 *Ampere*, or the current in a circuit which has an electro-motive force of 1 *Volt* and a resistance of one *Ohm.*

Capacity.—Unit of capacity is termed a *Farad.*

1 000 000 Microfarads or 10^{-9} absolute units of capacity .... = 1 *Farad.*

Heat.—Unit of heat is quantity required to raise one gramme of water from 0° C. to 1° C. of temperature.

Quantity.—Unit of Quantity, one *Coulomb*, and is the quantity of Electricity transferred by one ampere during one second.

Note.—For additional Elements, see p. 953.

Weights of Grain and Roots.

Following weights have been fixed by statute in many of the States; and these weights govern in buying and selling, unless a specific agreement to the contrary has been made.

Pounds in a Bushel.

Articles.	California.	Connecticut.	Delaware.	Illinois.	Indiana.	Iowa.	Kentucky.	Louisiana.	Maine.	Massachusetts.	Michigan.	Minnesota.	Missouri.	N. Hampshire.	New Jersey.	New York.	Ohio.	Oregon.	Pennsylvania.	Rhode Island.	Vermont.	Washington T.	Wisconsin.
Barley	50	—	—	48	48	48	48	32	—	46	48	48	48	—	48	48	48	46	47	—	46	45	48
Beans	—	—	—	60	60	60	60	—	—	—	—	—	60	—	—	62	—	—	—	—	—	—	—
Blue Grass Seed	—	—	—	14	14	14	14	—	—	—	—	—	14	—	—	—	—	—	—	—	—	—	—
Buckwheat	40	45	—	40	50	52	52	—	—	46	42	42	52	—	50	48	—	42	48	—	46	42	42
Castor Beans	—	—	—	46	46	46	—	—	—	—	—	—	46	—	—	—	—	—	—	—	—	—	—
Clover Seed	—	—	—	60	60	60	60	—	—	—	60	60	60	—	64	60	60	60	—	—	—	60	60
Dried Apples	—	—	—	24	25	24	—	—	—	—	28	28	24	—	—	—	—	28	—	—	—	28	28
Dried Peaches	—	—	—	33	33	33	—	—	—	—	28	28	33	—	—	—	—	28	—	—	—	28	28
Flaxseed	—	—	—	56	56	56	56	—	—	—	—	—	56	—	55	55	56	—	—	—	—	—	56
Hemp Seed	—	—	—	44	44	44	44	—	—	—	—	—	44	—	—	—	—	—	—	—	—	—	—
Corn	52	56	56	52	56	56	56	56	—	56	56	56	52	—	56	58	56	56	56	—	56	56	56
Corn in ear	—	—	—	70	68	68	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Corn Meal	—	—	—	48	50	—	50	—	50	50	—	—	—	—	—	—	—	—	—	50	—	—	—
[illegible]	—	—	—	80	70	—	—	—	—	—	—	—	80	—	—	—	—	—	—	—	—	—	—
[illegible]	32	28	—	32	32	35	33½	32	30	30	32	32	35	30	30	32	32	34	32	—	32	36	32
[illegible]	—	—	—	57	48	57	57	—	—	52	—	—	57	—	—	—	—	—	—	50	—	50	—
[illegible]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	60	—	—	—	—	—	—	—
[illegible]	—	60	—	60	60	60	60	—	60	—	—	—	60	60	60	60	—	60	—	60	60	60	60
[illegible]	54	56	—	54	56	56	56	60	—	56	56	56	56	—	56	56	56	56	56	—	56	56	56
[illegible]	—	—	—	—	—	—	—	—	50	50	—	—	—	—	—	—	—	—	—	50	—	—	—
[illegible]	—	—	—	—	50	50	50	—	—	—	—	—	50	—	—	56	—	—	—	—	—	—	—
[illegible]	[illegible]	[illegible]	—	45	45	45	45	—	—	—	—	—	45	—	—	44	—	—	—	—	—	—	[illegible]
[illegible]	[illegible]	[illegible]	60	60	60	60	60	60	—	60	60	60	60	—	60	60	60	60	60	—	60	60	60
[illegible]	[illegible]	[illegible]	—	20	—	20	20	—	—	—	—	—	20	—	—	—	—	—	—	—	—	—	—

Weight of Men and Women.

rage weight of 20000 men and women, weighed in Boston, 1864, was
, 141.5 lbs.; women, 124.5 lbs. Average of men, women, and chil-
105.5 lbs. A mass of people, densely packed, weighs 85 lbs. per sq. foot,
ccupying .8 of one sq. foot of area = 54450 per acre.

Weight of Horses.—(U. S.)

ght of horses ranges from 800 to 1200 lbs.

WEIGHT OF CATTLE.

To Compute Dressed Weight of Cattle.

E.—*Measure as follows in feet:*

lirth close behind shoulders, that is, over crop and under plate, iately behind elbow.

ength from point between neck and body, or vertically above n of cervical and dorsal processes of spine, along back to bone at d in a vertical line with rump.

multiply square of girth in feet by length, and multiply product ors in following table, and quotient will give dressed weight of s.

ition.	Heifer, Steer, or Bullock.	Bull.	Condition.	Heifer, Steer, or Bullock.	Bull.
....	3.15	3.36	Very prime fat...	3.64	3.85
fat......	3.36	3.5	Extra fat........	3.78	4.06
t.........	3.5	3.64			

RATION.—Girth of a prime fat bullock is 7 feet 2 ins., and length measured 4 feet 5 ins.

= 7.17, and $7.17^2 = 51.4$, which $\times$ 4′ 5″ and by 3.5 = 794.5 *lbs.* Exact as 799 *lbs.*

-1. Quarters of a beef exceed by a little, half weight of living animal. weighs about eighteenth part, and tallow twelfth part of animal.

parative Weights of Live Beeves and of Beef.

	Lbs.	Per cent.		Lbs.	Per cent.
....	2800	72 to 78	Bullocks.........	1550	61 to 64
....	2600	70 to 76	Heifers..........	1550	
....	2600		Bullocks.........	1260	58 to 61
....	2400	66 to 70	Heifers..........	1200	
....	2400		Bullocks.........	1050	57 to 58
....	2100	64 to 68	Heifers..........	1050	
....	2100		Bullocks.........	980	50 to 56
....	1800	63 to 66	Heifers..........	950	

Weight of Offal in a Beef and Sh

	BEEF. Lbs.	SHEEP. Lbs.	
lair....	56 to 98	8 to 16*	Kidneys, Heart, Liver, etc......
....	42 " 140	5 " 14	
ongue.	*28 " 49*	*6 " 11†*	Stomach, Entrails, etc.,
....	*21 " 35*	*2 " 3*	Blood................

ing 2 to 6 lbs. for fleece. † Including a to

To Compute Equivalents of Old and New U. S. and of Metric Denominations.

By Act of Congress, July 28, 1866.

RULE. — Divide fourth term by second, multiply quotient by first term, and divide product by third term.

Or, Ascertain relative ratio of first and second terms, and multiply result by ratio of third and fourth terms.

NOTE. — When result is required in French or other Metric denominations than those of U. S., use exact denominations, as, 61.025 387 for 61.022, 39.370 432 for 39.37, etc.

EXAMPLE 1. — If one gallon (1st), per sq. foot, yard, acre, etc. (2d); how many liters, (3d), per sq. foot, yard, acre, etc. (4th)?

$\frac{1}{1} \times 231 \div 61.022 \ldots\ldots\ldots = 3.7851$ *liters* or 3.7848 *liters*.

Or, $\frac{231}{144} = 1.604$, and $\frac{144}{61.022} = 2.3598$; hence, $1.604 \times 2.3598 = 3.7851$ *liters*.

NOTE. — In computing ratios, first term is to be divided by second, and fourth by third.

EXAMPLE 2. — If one ton per cube foot, how many kilograms per cube decimeter?

$\frac{61.022}{1728} \times 2240 \div 2.2046 = 35.881$ *liters*, or 35.882 *litres*.

MEASURES.

	By Act of Congress of U. S.		*By Metric Computation.*
1 Liter per sq. foot, etc. =	.2642 *Gallon per sq. foot*,	or	.264 2 *gallon*.
1 Liter per sq. meter . =	.0245 *Gallon per sq. foot*,	or	.024 5 *gallon*.
1 Gallon per sq. foot . =	40.746 *Liters per sq. meter*,	or	40.745 4 *litres*.
1 Sq. foot per acre . . . =	.2296 *Sq. meters per hectare*,	or	2.296 09 *metres*.

WEIGHTS AND PRESSURES.

Per sq. inch.	*By Act of Congress of U. S.* *Per sq. inch.*		*By Metric Computation.*
1 Centimeter . . . . . =	.3937 *Ins.*	or	.393 704 32 *Ins.*
1 Atmosphere . . . . =	6.6679 *Kilograms*,	or	6.667 8 *kilogrammes*.
1 Inch mercury . . =	2.54 *Centimeters*,	or	2.54 *centimetres*.
1 Pound . . . . =	453.6029 *Grams*,	or	453.592 6 *grammes*.
1 Kilogram . . . . . . =	317.4624 *Lbs. per sq. foot*,	or	317.465 *lbs.*

NOTE. — 30 ins. of mercury at 62° = 14.7 *lbs. per sq. inch*; hence, 1 *lb.* = 2.0408 *ins.*, and a centimeter of mercury = 30 ÷ .3937 for U. S. computation, and 30 ÷ .393 704 32 for French or Metric.

POWER AND WORK.

1 Horse-power = *Cheval* or *Cheval-vapeur* = $\overline{4500\ k \times m} = 33\,000 \div (4500 \times 2.2046 \times \overline{39.37} \div 12) = 1.013\,88$ *chevaux*.

1 Cheval or Cheval-vapeur ($75\ k \times m$ per second) = *horse-power*.

$(4500 \times 2.2046 \times \overline{39.37} \div 12) \div 33\,000 = .9863$ *horse-power*.

By A[illegible] [illegible]ress of U. S.	*By Metric Computation.*
[illegible] = 7.233 *foot-lbs.*; hence,	
[illegible] = .138 26 *Kilogrammeter*,	or .138 25 *kilogrammetre*.
[illegible] .0279 *Cube meter per cheval*,	or .0279 *cheval*.
[illegible] 47 38 *Kil[illegible]* per cheval,	or .447 38 *kilogramme*.
[illegible] feet per HP,	or 35.8058 HP.

TEMPERATURES.

oric or French unit = 3.968 *Heat-units*, and 1 heat-unit = 1 ÷ 3.968 *caloric.*
S. Mechanical equivalent (772 foot-lbs.) = 772 ÷ 7.233 = 106.733 *mmeters* and 106.733 *kilogrammetres.*
nch Mechanical equivalent (423.55 $k \times m$) = 3.280833 × 2.2046 × = 3063.505 *foot-lbs.*, or 3063.566 *foot-lbs. Metric.*
t-unit per pound = .5556 *Kilogram*, or .5556 *kilogramme.*
t-unit per sq. foot = .2715 *Caloric per sq. meter*, or .2713 *per sq. metre.*

VELOCITIES.

t per second.......... = .3047 *Meter per second*, or .3047 *metres.*
e per hour............ = .447 " " " or .447 "

MEASURES OF TIME.

o thirds = 1 second.	60 minutes = 1 degree.
o seconds = 1 minute.	30 degrees = 1 sign.

360 degrees = 1 circle.

or *apparent time* is that deduced from observations of the Sun, ame as that shown by a properly adjusted sun-dial.

Solar time is deduced from time in which the Earth revolves xis, as compared with the Sun; assumed to move at a mean ts orbit, and to make 365.242 218 revolutions in a mean Solar rian year.

al time is period which elapses between time of a fixed star meridian of a place and time of its return to that place.

rd unit of time is the *sidereal day.*

l day = 23 *h.* 56 *m.* 4.092 *sec.* in *solar* or *mean time.*

l year, or revolution of the earth, 365 *d.* 5 *h.* 48 *m.* 47.6 *sec.* in *solar ime* = 365.242 24 *solar days.*

ay, mean = 24 *h.* 3 *m.* 56.555 *sec.* in *sidereal time.*

ar (Equinoctial, Calendar, Civil or Tropical) = 365.242 218 *solar* 5 *d.* 5 *h.* 48 *m.* 47.6 *sec.*

ay commences at midnight. *Astronomical day* commences at e civil day, having same designation, that is, 12 hours later ivil day.

or *sea day* commences 12 hours before civil time or 1 day ronomical time.

e was introduced in England in 1752.

n Russia days are reckoned by Old Style, a orian record.

MEASURES OF VALUE.

10 mills = 1 cent.	10 dimes = 1 dollar.
10 cents = 1 dime.	10 dollars = 1 eagle.

Standard of gold and silver is 900 parts of pure metal and 100 of alloy in 1000 parts of coin.

Fineness expresses quantity of pure metal in 1000 parts.

Remedy of the Mint is allowance for deviation from exact standard fineness and weight of coins.

Nickel cent (old) contained 88 parts of copper and 12 of nickel.
Bronze cent contains 95 parts of copper and 5 of tin and zinc.
Pure Gold 23.22 grains = $1 00. Hence value of an ounce is $20.67.183+.
Standard Gold, $18.60.465+ per ounce.

WEIGHT, FINENESS, ETC., OF U. S. COINS.

Gold.

Denomination.	Weight of Coin.		of Pure Metal.	Denomination.	Weight of Coin.		of Pure Metal.
	Oz.	Grs.	Grs.		Oz.	Grs.	Grs.
Dollar.........	.053 75	25.8	23.22	Half Eagle	.268 75	129	116.1
Quarter Eagle..	.134 375	64.5	58.05	Eagle..........	.537 5	258	232.2
Three Dollar...	.161 25	77.4	69.66	Double Eagle...	1.075	516	464.4

Silver.

Dime..........	.080 375	38.58	34.722	Half Dollar.....	.401 875	192.9	173.61
20 Cent........	.160 75	77.16	69.444	Trade Dollar....	.875	420	378
Quarter Dollar .	.200 937 5	96.45	86.805	Silver Dollar...	.859 375	412.5	371.25

Copper and Nickel.

	Weight.	Copper.	Tin and Zinc.		Weight.	Copper.	Tin and Zinc.
	Grains.	Per cent.	Per cent.		Grains.	Per cent.	Per cent.
One Cent....	48	95	5	Three Cents.	30	75	25
Two Cents...	96	95	5	Five Cents..	77.16	75	25

Tolerance.—*Gold*, Dollar to Half Eagle, .25 grains. Eagles, .5 grains. —*Silver*, 1.5 grains for all denominations.—*Copper*, 1 to 3 cents, 2 grains; 5 cents, 3 grains.

Legal Tenders.—*Gold*, unlimited.—*Silver*. Dollars of 412.5 grains unlimited; for subdivisions of dollar, $10. (Trade dollars [420 grains] are not legal tender.)—*Copper* or *cents*, 25 cents.

NOTE.—Weight of dollar up to 1837 was 416 grains, thence to 1873, 412.5. Weight of $1000, @ 412.5 gr. = 859.375 oz.

BRITISH standards are: *Gold*, $\frac{11}{12}$ of a pound,* equal to 11 parts pure gold and 1 of alloy; *Silver*, $\frac{111}{120}$ of a pound, or 37 parts pure silver and 3 of alloy ·25 fine.

· ounce of standard gold is coined into £3 17*s.* 10*d.* 2*f.*, and an ·lver into 5*s.* 6*d.* 1 lb. silver is coined into 66 shillings. ·roportion of 2 shillings to pound avoirdupois.

·86.65; hence $\frac{1}{240}$ of this = value of 1 penny =

---

be divided into 24 equal parts or carats, hence the pro·
·.

To Compute Value of Coins.

-Divide product of weight in grains and fineness, by 480 an ounce), and multiply result by value of pure metal per

tiply weight in ounces by fineness and by value of pure metal

1.—When fine gold is $20.67.183+ per oz., what is value of a British

ing tables, p. 40, Sovereign weighs .2567 oz., and .2567 × 480 = 123.216 has a fineness of .9165.

$$\text{Hence, } \frac{123.216 \times .9165}{480} \times 20.67.183+ = \$4.86.34.$$

2.—When fine silver is $1.15.5 per oz., what is value of U. S. Trade dollar? p. 38, Dollar weighs .875 oz. and has a fineness of .900.

Hence, .875 × .900 × 1.15.5 = 90.956 25 *cents*.

3.—A 4-Florin (Austrian) weighs 49.92 grains and has a fineness of .900. value?

$$\frac{49.92 \times .900}{480} \times 20.67.183+ = \$1.93.49.$$

vert U. S. to British Currency and Contrariwise.

—Divide Cents by 2.027 71 – (2.027 708 33), or, Multiply by (.493 118 26), and result is Pence.

iply Pence by 2.027 71 –, or divide by .49312 –, and result

—What are 100 cents in pence?

100 × .493 12— = 49.312— *pence* = 4*s.* 1.312*d.*

s a Pound sterling in cents?

20 × 12 = 240 *pence*, which × 2.027 71— = $4 86.65.

FOREIGN MEASURES OF VALUE.

t, Fineness, and Mint Values of Foreign Silver and Gold Coins.

s of Congress, Regulations of the Mint, and Reports of its Directors.

; Value of silver coins is necessarily omitted, as the value of variable element. Hence, in order to compute current value r coin, the price of fine or a given standard of silver being

| as per above rule to compute value of coins.

se of silver should be taken as that of the London market for andard (925 fine), it being recognized as t d value, ning rates in all countries.

—If it is required to determine value of a Mexic

67.5 *oz.* .903 *fine.* Value of Silver in London 52 *ents.*

$$\frac{67.5 \times .903}{925} = .846\,867— \text{ and } 106.9616 \times .846\,867.$$

Weight and Mint Values of Foreign Coin.

(The Value of the Silver Coins is based on their Value on January, 1888.)

Countries given in Italics have not a National Coinage.

Country and Denomination.	Weight.	Fineness.	Pure Silver or Gold.	Current or Nominal.	Value. Gold. U. S.	British.
	Oz.	Thous's.	Grains.	Cents.	$ c.	£ s. d.
Arabia.						
Piastre or Mocha Dollar	—	—	—	83.14	—	—
Argentine Republic.						
Dollar = 100 Centisimos	—	—	—	50.69	—	—
Peso, Double	—	—	—	—	96.5	—
Australasia. Same as British.						
Australia.						
Sovereign, 1855	.256.5	916	—	—	4.85.7	19 11.5
Pound, 1852	.281	916.5	—	—	5.32.37	1 1 10.5
Austria.						
Kreutzer (copper)	—	—	—	.41	—	.8
Florin, new	.397	900	171.47	—	34.5	—
Dollar, "	.596	900	257.47	—	—	—
4 Florins	.104	900	—	—	1.93.49	7 11
Ducat	.112	986	—	—	2.28.3	9 4.6
Souverain	.363	900	—	—	6.75.4	1 7 9.1
Belgium. Same as France.						
Bolivia.						
Centena	—	—	—	.75	—	.37
Dollar, new	.801	900	346.03	—	69.9	—
Doubloon, 1827–36	.867	870	362.06	—	15.59.3	3 4 1
Brazil.						
Rei	—	—	—	.547	—	.27
Milreis	.028.8	916.66	12.67	—	.54.59	26.98
Double Milreis	.82	918.5	393.6	—	—	—
20 Milreis, 1854–56	.575	917.5	—	—	10.90.6	2 4 9.84
Moidore, 4000 Reis	.261	914	—	—	4.92	1 0 2.63
Canada.						
Mil, sterling	—	—	—	.1	—	.05
Cent "	—	—	—	1.01	—	.5
20 Cent, currency	.15	925	66.6	—	—	—
25 " "	.187 5	925	83.25	—	—	—
Penny "	—	—	—	1.52	—	.75
Shilling "	—	—	—	—	—	—
Dollar, sterling	—	—	—	—	1	4 2
4 " = 20 shillings, currency	—	—	—	—	3.97.43	16 4
Pound " "	—	—	—	—	3.99.97	16 5.75
Cape of Good Hope. Same as British.						
Central America.						
4 Reals	.027	875	11.34	—	—	—
Dollar	.866	850	353.33	—	—	—
2 Escudos	.209	853.1	—	—	3.68.8	15 1.88
Doubloon ante 1834	.869	833	—	—	14.96.39	3 1 5.97
Chili.						
Centavo	—	—	—	.9	—	4.
Dollar, new	.801	900.5	346.22	—	91.2	—
10 Pesos	.492	900	—	—	9.15.4	1 17 7.43
Doubloon	.867	870	—	—	15.59.3	3 4 1
China.						
Cash, Le	—	—	—	.14	—	.07
10 Cents, Leang	.087	901	37.98	—	—	—
Dollar	.866	901	374.63	—	—	—
Cochin China.						
Mas, 60 Sapecks	—	—	—	6.75	—	[illegible]
10 Mas, 1 Quan	—	—	—	67.52	—	[illegible]

Weight and Mint Values.

Country and Denomination.	Weight.	Fineness.	Pure Silver or Gold.	Current or Nominal.	VALUE. Gold. U. S.	British.
	Oz.	Thous'ds.	Grains.	Cents.	$ c.	£ s. d.
Cuba.						
Same as Spain.						
Colombia.						
Centaro	—	—	—	1.01	—	.5
Peso, new	.801	900	346.03	—	69.9	—
4 Escudos	.433	844	—	—	7.55.5	1 11 0.58
Doubloon, old	.867	870	—	—	15.59.3	3 4 1
Costa Rica.						
Same as Mexico.						
Denmark.						
Mark, 16 Skilling	—	—	—	8.94	—	4.39
Crown	.025	900	—	—	26.8	13.22
2 Rigsdaler	.927	877	390.23	—	—	—
10 Thaler	.427	895	—	—	7.90	1 12 5.6
East Indies.						
See Hindostan and Japan.						
Ecuador.						
Centaro	—	—	—	1.01	—	.5
Peso	.801	900	346.03	—	69.9	—
England.						
Penny	.304	—	—	2.02+*	—	1
Groat	.060.4	925	26.82	—	—	—
Shilling, new	.182.5	924.5	80.99	—	—	—
" average	.178	925	79.03	—	—	—
Half Crown	.454.5	925	201.8	—	—	—
Florin	.363.6	925	161.44	—	—	—
Sovereign or Pound, new	.256.7	916.5	—	—	4.86.65	1 0 0
" " average	.256.2	916.5	—	—	4.85.1	1 0 0
Egypt.						
Piastre, 40 Paras	.04	755	14.5	—	4.9	—
Guinea, Bedidlik	.275	875	—	—	5. 0.52	1 0 6.84
Pound	.275	875	—	—	4.97.4	1 0 5.3
Purse, 5 Guineas	1.375	875	—	—	25. 2.6	5 2 10.2
France.						
Centime	.032	—	—	.2	—	.1
Sou, 5 Centimes	.161	—	—	1.01	—	.5
Franc, 100 Centimes	.161	900	69.55	—	19.3	—
5 Francs	.804	900	347.76	—	96.45	—
20 Francs, Napoleon, new	.207.5	899	—	—	3.85.8	15 10.26
25 Francs 20 centimes = £1 Stg.						
Germany.						
Groschen, 10 Pfenning	—	—	—	2.38	—	1.175
Mark, 10 Groschen	.012.8	900	—	—	23.8	11.74
10 Marks	.128	900	—	—	2.38.24	9 9.5
Thaler	.595	900	257.04	—	—	—
Ducat	.112	986	—	—	2.28.38	9 4.63
Greece and Ionian Islands.						
Same as France.						
Drachma, 100 Lepta	.010.4	900	—	—	19.3	9.5
5 Drachmas	.719	900	310.61	—	—	—
20 Drachmas	.185	900	—	—	44.2	14 1.75
Pound	—	—	—	—	5. 6.11	1 0 9.6
Guatemala.						
Same as Mexico.						
Guiana, British, French, and Dutch.						
Same as that of their Countries.						
Hanse Towns.						
Mark	.012.8	900	—	—	23.8	11.74
Holland.						
Cent	—	—	—	.4	—	—

* 2.027 71 cents.

Weight and Mint Values.

Country and Denomination.	Weight.	Fineness.	Pure Silver or Gold.	Current or Nominal.	Value in Gold. U. S.	Value in Gold. British.
	Oz.	Thous'ᵃ.	Grains.	Cents.	$ c.	£ s. d.
Holland.						
Florin or Guilder, 100 cents.	.021.6	900	—	—	41.2	1 8
10 Guilders	.215	899	—	—	3.99.7	16 5.11
Hindostan.						
Rupee	.374	916.5	164.53	—	—	1 10.5
Honduras.						
Same as Mexico.						
Italy.						
Same as France.						
Lira. 100 Centimes	.16	835	65.12	—	19.3	—
Scudo	.864	900	373.24	—	—	—
Indian Empire.						
Pic, nominal	—	—	—	.25	—	.125
Anna "	—	—	—	3.03	—	1.5
Rupee,* 16 Annas	.375	916.5	165	—	35.2	—
10 Rupees, and 4 Annas	—	—	—	—	4.86.65	1 0 0
Mohur, 15 Rupees	.375	916.5	—	—	6.84.36	1 8 1.5
Japan.						
Sen	—	—	—	1	—	.5
Itzebu, new	.279	890	119.19	—	—	—
Yen, 100 Sen	.866.7	900	374.4	—	75.3	—
" "	.053.6	900	—	—	99.72	4 1.18
Cobang, old	.289	572	—	—	3.57.6	14 8.35
" new	.362	568	—	—	4.44	18 2.06
20 Yen	1.072	900	—	—	19.94.4	4 1 11.6
Java.						
Same as Holland.						
Liberia.						
U. S. Currency.						
Malta.						
12 Scudi = 1 Sovereign	—	—	—	—	4.86.65	1 0 0
Mexico.						
Peso, new	.867.5	903	377.17	—	75.9	4 2
Maximilian	.861	902.5	372.98	—	—	—
Doubloon, new	.867.5	870.5	—	—	15. 6.1	3 4 1.88
20 Pesos, Republic	1.081	873	—	—	19.51.5	4 0 2.4
Morocco.						
Ounce, 4 Blankeels	—	—	—	—	—	—
10 Ounces, Mitkeel	—	—	—	—	—	—
Naples.						
Scudo	.844	830	336.25	—	—	—
6 Ducati	.245	996	—	—	5. 4.4	1 0 8.75
Netherlands.						
Same as Holland.						
New Brunswick.						
Same as Canada.						
Newfoundland.						
Same as Canada.						
New Granada.						
Dollar 1857	.803	896	—	—	—	—
Doubloon, Popayan	.867	858	—	—	15.37.8	3 3 3.59
Norway.						
Like to Denmark.						
Mark, 24 Skillingen	—	—	—	21.63	—	10.66
Nova Scotia.						
Same as Canada.						
Persia.						
Keran	—	—	—	22.81	—	11.85
		—	—	—	—	—

* [illegible] shillings sterling.

Weight and Mint Values.

Denomination.	Weight.	Fineness.	Pure Silver or Gold.	Current or Nominal.	Value. Gold. U. S.	British.
	Oz.	Thous's.	Grains.	Cents.	$ c.	£ s. d.
....	.766	900	341.01	—	—	—
....	.802	900	346.46	—	69.9	—
ld	.867	868	—	—	15.55.7	3 3 11.22
, 10000 Reis	.308	912	—	—	10.81.78	2 4 5.5
....	.095	912	—	—	10.8	—
....	.322	835	129.06	—	—	—
....	—	500	—	.77	—	.38
Rouble..........	.667	875	277.73	—	55.9	—
....	.21	916.6	—	—	3.97.6	16 4.8
unds.						
ency.						
....	.16	835	65.12	—	—	—
....	—	—	—	.19	—	.095
o, Peseta	.16	835	64.13	—	19.3	—
seta	.8	900	345.6	—	92.6	—
....	.268	896	—	—	4.96.4	1 0 4.8
....	.270.8	896	—	—	5. 1.5	1 0 7.32
ns=1 U.S. Dollar.						
100 Ore..........	.273	750	98.28	—	—	—
....	1.092	750	393.12	—	—	—
Francs..........	.104	900	—	—	1.93.5	7 11.42
nce.						
o Cents.........	—	—	—	6.33	—	3.125
Karubs..........	—	—	—	11.83	—	5.83
....	.511	898.5	220.38	—	—	—
....	.161	900	—	—	2.99.5	12 3.7
Paras	—	—	—	4.39	—	2.16
....	.77	830	306.77	—	—	—
Medjidie........	.231	915	—	—	4.36.9	18 0
equin...........	.112	900	—	—	2.31.3	9 6.1
Mahbub	—	—	—	74.3	63	3 0.89
Centimes.......	—	—	—	—	—	—
British.						
ngland.						
....	—	—	—	1	—	.5
ranc...........	—	—	—	—	19.3	—

Memoranda.

ronze coins 9.5 copper, 4 tin, and 1 zinc.
s.—Monetary system same as that of German Empire.
n.—The Centime is termed a Rappe.
Peseta piece is 19*s.* 9.5*d.* Stg.; Real vellon was 2.5*d.* Stg.
coins same weight and fineness as those of France.
Tari and 4 Grani = 1 *Shilling* Sterling.
Para = .061 5*d. Sterling*, and 97.22 Piastres = 1 Sovereign.
ia.—1 Lac Rupees = £10000 Sterling. In CEYLON, Rupee = 1

ENGLISH AND FRENCH MEASURES AND WEIGHTS.

MEASURES OF LENGTH.

[illegible].—Imperial standard yard is referred to a natural standard, [illegible] a pendulum 39.1393 ins. in length vibrating seconds in vacuo in London, at level of sea; measured between two marks on a brass rod, at temperature of 62°.

[illegible] In consequence of destruction of standard by fire in 1834, and difficulty of replacing it by measurement of a pendulum, the present standard is held to be [illegible] 1 part in 17230 less than that of U. S., equal to 3.07 ins. in a mile.

Miscellaneous.

Land.—Woodland pole or perch or Fen .... = 18 *feet.*
Forest pole .... = 21 "

Irish mile .... = 2240 *yards.* | Scotch mile ..... = 1984 *yards.*

[illegible] 10 cables, or 1000 fathoms, or 6080.27 feet, or 1.1516 Statute miles.
1 *Admiralty or Nautical mile or knot* = 6080 *feet.*

3 miles = 1 league. 60 Nautical or 69.094 Statute miles or 20 Leagues = 1 *degree.*

Mean length of a minute of Latitude at mean level of the sea = 1.1451 *statute miles.*

Nautical mile is taken as length of a minute at the Equator.

Nautical fathom is 1000th part of a nautical mile, and averages about .0125 longer than the common fathom.

[illegible].—Standard Metre or unit of measurement is defined as the ten millionth part of the terrestrial meridian, or the distance from the Equator to the Pole, passing through Paris. Actual standard is a platinum [illegible], deposited in the Palais des Archives, Paris.

Metric Length in Inches, Feet, etc.

[illegible]	Metres.	Inches.	Feet.	Yards.	Miles.
[illegible]	.001	.03937		—	—
[illegible]	.01	.3937		—	—
[illegible]	.1	3.93704		—	—
[illegible]	1	39.37043	3.28087	1.09362	—
[illegible]	10	—	32.80869	10.93623	—
[illegible]	100	—	328.0869	109.3623	—
[illegible]	1000	—	3280.869	1093.6231	.62138
[illegible]	10000	—		10936.231	6.21377

[illegible] metre see p. 27.

Old Measure.

[illegible] = 1.949 *metres.*	1 Terrestrial league = 4.444 *kilometres.*
[illegible] = 1.949 *kilometres.*	1 Nautical league . = 5.555 "
[illegible] = 1.875 "	1 Arpent .... = 900 *sq. toises.*

MEASURES OF SURFACE.

[illegible].—Same as that of United States of America.

Miscellaneous.

Builders. 1 [illegible]cial part .... = 1 *square inch.*
.... = 1 *inch.*
.... = *square foot.*
[illegible], 9 inches deals, and

French.

Metric Surfaces in Square Inches, Feet, etc.

Denomination.	Sq. Inches.	Sq. Feet.	Sq. Yards.	Sq. Acres.
are millimetre...........	.001 55	—	—	—
" centimetre...........	.155 003	—	—	—
" decimetre...........	15.500 309	.107 641	—	—
" *Metre* or *Centiare*	1550.030 916	10.764 104	1.196 01	—
" dekametre or *are*.....	—	1076.410 358	119.601 15	.024 711
" hektometre or *hectare*	—	—	11 960.115 09	2.471 098
" kilometre...........	—	—	—	247.109 816
" myriametre*.........	—	—	—	24 710.981 6

* Equal 38.610 908 *sq. miles.*

Old System.

square inch = 1.135 87 *inches.*
toise = 6.394 6 *feet.*
arpent (Paris) = 900 square toises = 4089 *square yards.*
arpent (woodland) = 100 square royal perches = 6108.24 *square yards.*

MEASURES OF VOLUME.

perial gallon measures 277.123 cube ins., but by Act of Parliament its volume is 277.274 cube ins., equal to 10 lbs. avoirdupois of led water, weighed in air, at temperature of 62°, barometer at 30 s. 6.2355 gallons in a cube foot.

perial bushel, 18.5 ins. internal diameter, 19.5 external, and 8.25 pth, contains 2218.192 *cube ins.*, and when heaped in form of a cone, at least .75 depth of the measure, must contain 2815.4872 *ins.* or 1.6293 *cube feet.*

in.—1 quarter = 8 *bushels* or 10.2694 *cube feet.*

sels.—1 ton displacement = 35 *cube feet*; 1 ton freight by measure = 40 *cube feet.*

n internal capacity = 100 *cube feet*, and 1 ton ship-builders = 94 *eet.*

lish standard No. 5 is .008 grain heavier than the pound, and U. S. pound is ain lighter than English.

Wine and Spirit Measures.

4 quarts (231 cube ins.)		....	= .8333 *Imperial gallon.*
10 gallons		....	= 1 *anchor.*
18 "	(15 imperial)	....	= 1 *runlet.*
31.5 "	26.25 "	....	= 1 *barrel.*
42 "	35 "	....	= 1 *tierce.*
63 "	52.5 "	....	= 1 *hogshead.*
84 "	70 "	....	= 1 *puncheon.*
126 "	105 "	....	= 1 *pipe* or *butt.*
2 pipes or 3 puncheons		....	= 1 *tun.*

Ale and Beer Measures.

	Imp'l gall's.		Imp'l gall's.
s (282 cube ins.) .. =	1.017	2 kilderkins = 1 barre	
s = 1 *firkin* ..... =	9.153	54 gallons = 1 hogshe	
= 1 *kilderkin* ... =	18.306	108 " = 1 butt ..	

Apothecaries' or Fluid Measures.

1 drop .... = 1 grain.
60 drops .... = 1 drachm.
4 drachms .... = 1 tablespoon.
2 ounces (875 grains) = 1 wineglass.

Coal Measures.

50 pounds .... = 1 *cube foot.*
88 " .... = 1 *bushel.*
9 bushels .... = 1 *vat.*
80 or 84 pounds = { 1 *London* or *Newcastle bushel.*
90 or 94 " = 1 *Cornish* "
93 pounds .... = 1 *Welsh bushel.*
3 heaped bush. = 1 *sack.*
10 sacks ..... = 1 *ton.*

12 sacks .... = 1 *chaldron.*
1 chaldron ..... = 58.6548 *cube ft.*
5.25 chaldrons .. = 1 *room.*
1 London chaldron = 26.5 *cwts.*
1 Newcastle " = 53 "
1 ton .... = 44.5 *cube feet.*
1 room .... = 7 *tons.*
21 chaldrons ..... = 1 *score.*
1 barge or keel .. = 21.2 *tons.*

Miscellaneous.

1 last corn .... = 80 *bushels.*
1 ton water ...... = 35.9 *cube feet.*
1 dicker hides .... = 10 *skins.*
1 last hides ...... = 20 *dickers.*
1 barrel tar ...... = 26.5 *gallons.*
6 bushels wheat .. = 1 *sack flour.*
1 clove .... = 7 *pounds.*
1 score .... = 20 "
1 sack flour ...... = 28.2 "
1 truss straw ..... = 36 "

1 truss old hay ..... = 50 *pounds.*
1 " new " ..... = 60 "
1 bushel oats ...... = 40 "
1 " barley .... = 47 "
1 " wheat ..... = 60 "
1 cube yard new hay = 84 "
1 " " old " = 126 "
1 quintal .... = 100 "
1 boll .... = 140 "
1 sack wool .... = 364 "

35.9 *cube feet* = 1 ton water.

Liquid.

1 wine gallon = 231 *cube ins.*
1 beer " = 282 " "
1 litre ...... = .220 09 *gallon.*
1 gallon .... = 4.544 *litres.*
1 cube foot .. = 6.2321 *gallons.*
1 anker .... = 8.333 "

1 hogshead wine .. = 52.5 *gallons.*
1 " beer ... = 54.918 "
1 puncheon wine .. = 70 "
1 pipe or butt wine = 105 "
1 " " " beer = 109.836 "
1 tun .... = 210 "

1 ton water 62° = 224 *gallons.*

Builders.

1 solid part .... = 12 *cube ins.*
12 " parts ...... = 1 "*inch.*"
12 "inches" .... = 1 *cube foot.*
1 load timber, rough = 40 " *feet.*
1 " " hewn = 50 " "
1 " lime .... = 32 *bushels.*
1 " sand .... = 36 "

1 square .... = 100 *sq. feet.*
1 bundle laths ..... = 120 *laths.*
1 rod brickwork ... = 306 *cube feet.*
1 rood masonry ... = 648 " "
Batten, in section .. = 7 × 2.5 *ins.*
Deal, " " .. = 9 × 3 "
Plank, " " .. = 11 × 3 "

Metric Volumes in Cube Inches, Feet, etc.

Denominations.	Litres.	Gills.	Pints.	Quarts.	Gallons.	Bushels.	Quarters.
Centilitre....		[illegible]	[illegible]	—	—	—	—
Decilitre....				—	—	—	—
[illegible]				[illegible]	.2201	—	—
					2.2009	.275 11	—
					[illegible]	2.751 13	.3439
					[illegible]	27.511 35	3.4389

Wood Measure.

Stere or cube metre = 35.3150 *cube feet* or 1.308 *cube yards.*
Voie de bois (Paris) = 70.6312 *cube feet;* 1 voie de charbon (charcoal) .063 *cube feet;* 1 corde = 4 cube metres = 141.26 *cube feet.*

MEASURES OF WEIGHT.

ISH.—1 Troy grain = .003 961 cube inches of distilled water.
1 Troy pound = 22.815 689 cube inches of water.
1 Avoir. drachm = 27.343 75 Troy grains.

Avoirdupois.

achms, or 5 grains ...... = 1 ounce.	8 pounds .. = 1 stone (for meat).
unces, or grains ...... = 1 pound.	14 " .. = 1 stone.
	28 " .. = 1 quarter.
	112 " .. = 1 cwt.

20 hundredweights ...... = 1 ton.

grain, of which there are 7000 to the pound avoirdupois, is same as grain, of which there are by the revised table 7000 to the Troy pound. nce Troy pound is equal with the Avoirdupois pound.
Wales, the iron ton is 20 cwt. of 120 lbs. each.

Troy.

ins .... = 1 dwt.	16 ounces .... = 1 pound.
nyweights, or 7.5 grains .. = 1 ounce.	25 pounds .... = 1 quarter.
	4 quarters, or 100 pounds = 1 cwt.

this are weighed gold, silver, jewels, and such liquors as are sold by

old Troy ounce to the Avoirdupois ounce was as 480 grains, the of the former, to 437.5 grains, weight of the latter; or, as 1 to .9115.

Apothecaries.*

437.5 grains = 1 ounce. | 16 ounces = 1 pound.

French.

Metric Weights in Avoirdupois.

ominations.	Grammes.	Grains.	Ounces.	Pounds.	Ton.
mme	001	.015 43	—	—	—
mme.........	.01	.154 32	—	—	—
nme	.1	1 543 23	—	—	—
....	1	15.432 35	—	—	—
mme.........	10	154.323 49	.3527	—	—
amme........	100	1 543.234 87	3.5274	.220 46	—
mme†.........	1 000	15 432.348 74	35.2739	2.204 62	—
mme........	10 000	—	—	22.046 21	—
....	100 000	—	—	220.462 12	—
r Ton........	1 000 000	—	—	2204.621 25	.9842

† Kilogramme = 2 *lbs.* 3 *oz.* 4 *drachms*, 10.4734 *grains.*

—For the values of the prefixes, as Milli, Centi, etc., see p. 27.

Old System.

n .. = 0.8188 *grains Troy.*	1 ounce = 1.0780 *oz. Avoirdupois.*
s .. = 58.9548 "	1 livre = 1.0780 lbs.

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* As by revised Pharmacopœia.

FOREIGN MEASURES AND WEIGHTS.

It being wholly impracticable to give all the denominations of measures and weights of all countries, the following cases are selected as essential and as exponents.

With parent countries, as England, France, etc., their denominations extend to their colonies and dependencies. Thus, the denominations of England extend to Canada, a large portion of the East and West Indies, and parts of South America, and those of France to a part of the West Indies, Algiers, etc.

Abyssinia.

Pic, Stambouili	26.8 ins.
" geometrical	30.37 "
Madega	3.466 bush.
Ardeb	34.66 "
" Musuah	83.184 "
Wakea	400 grains.
Mocha	1 Troy oz.
Rottolo	10 " "

Also, same as in Egypt and Cairo.

Africa, Alexandria, Cairo, and Egypt.

Cubit	20.65 ins.
Derah	25.49 "
Pic, cloth	26.8 "
" geometrical	29.53 "
Kassaba, 4.73 Pics	11.65 ft.
Mile	2146 yds.
Feddan al-risach	.55248 acre.
Roobak	1.684 galls.
Ardeb	4.9 bush.
Rottol	.9821 lb.

Distances are measured by time.

A Maragha = 15 Déréghé or 1 hour.

Aleppo and Syria.

Dra Mesrour	21.845 ins.
Pic	26.63 "

Road Measures are computed by time.

Algeria.

Rob, Turkish	3.11 ins.
Pic, "	24.92 "
" Arabic	18.89 "

Also Decimal System.

Alicante.

Palmo	8.908 ins.
Vara	35.632 "

Amsterdam.

Voet	11.144 ins.
El	21.979 "
Faden	5.57 ft.
Lieue	6.383 yds.
Maat	1.6728 acres.
Morgen	2.0095 "
Vat	40 cub. ft.

Also Decimal System.

Antwerp.

Fuss	11.275 ins.
Elle, cloth	[illegible]
Corde	[illegible]
Bonnier	[illegible]

Arabia, Bassora, and Mocha.

Foot, Arabic	1.0502 ft.
Covid, Mocha	19 ins.
Guz, "	25 "
Kassaba	12.3 ft.
Mile, 6000 feet	2146 yds.
Baryd, 4 farsakh	21 120 "
Feddan	57 600 sq. ft.
Noosfia, Arabic	138 cub. ins.
Gudda	2 galls.
Maund	3 lbs.
Tomand	168 "

Other Measures like those of Egypt.

Argentine Confederation, Paraguay, and Uruguay.

Fanega	1.5 bush.
Arroba	25.35 lbs.
Quintal	101.4 "

Also Decimal System in Argentine Confederation and Paraguay.

Australasia.

Land Section	80 acres.

Other Measures same as English.

Austria.

Zoll	1.0371 ins.
Fuss	1 0371 ft.
Meile	24 000 ft.
Klafter, quadrat	35.854 sq. yds.
Jochart	6.884 "
Cube Fuss	1.1155 cub. ft.
Achtel	1.692 galls.
Eimer	12.774 "
Viertel	3.1143 "
Metze	1.6918 bush.
Unze	.8642 grains.
Pfund (1853, 500 grammes),	1.2347 lbs.
Centner	123.47 "

Also Decimal System.

Babylon.

Pachys Metrios	18.205 ins.

Baden.

Fuss	11.81 ins.
Klafter	5.9055 ft.
Ruthe	9.8427 "
Stunden	4860 yds.
Morgen	.8896 acre.
Stutze	3.3014 galls.
[illegible]	4.1268 bush.
[illegible]	1.1023 lbs.

Also Decimal System.

Bagdad.

.... 31.665 ins.

Barbary States.

s linen.............. 18.62 ins.
cloth.............. 26.49 "
oli.................. 21.75 "

Batavia.

.... 12.357 ins.
.... 27 "
.... 27.75 "

Bavaria.

.... 11.49 ins.
.... 5.745 36 ft.
.... 3.1918 yds.
.... 8060 "
uadrat.......... 10.1876 sq. yds.
r Tagwerk...... .8416 acre.
ube........... 4.097 cub. yds.
.... 15.058 56 galls.
.... 6.119 "
.... 1 0196 bush.
.... 8642 grains.

Also Decimal System.

Belgium.

.... 2.132 yds.

Also Decimal System.

Benares.

lor's.................. 33 ins.

l, Bombay, and Calcutta.

.... 3 ins.
.... 9 "
ibar.......... 10.46 ins.
.... 18 "
ibay.......... 27 "
gal............ 36 "
inimum .... 3.417 ft.
gal............ 1.136 miles.
utta .... 1.2273 "
.... 9.8175 sq. yds.
engal .... .3306 acre.
ombay .... .8114 "
tory........... .68 cub. ins.
mbay.......... 12.704 cub. ft.
ibay........... 1.234 pints.
.... 4.4802 galls.
.... 112.0045 "

nd Grain measured by weight.

Bohemia.

gue................. 11.88 ins.
erial .... 12.45 "

Also same as Austria.

ia, Chili, and Peru.

.... 33.333 ins.
.... 1.5888 acres.
.... .74 gall.
.... 1.572 "
.... 1.014 lbs.
.... 25.36 "

in Spain; now Decimal in Chili and Peru.

Brazil.

Palmo, Bahia............. 8.5592 ins.
Vara.................... 3.566 ft.
Braca................... 7.132 "
Geira.................... 1.448 acres.

Also same as Portugal, and sometimes as in England.

Buenos Ayres.

Vara...................... 2.84 ft.
Legua..................... 3.226 miles.
Suertes de Estancia.... 27 000 sq. varas.

Also same as Spain.

Burmah.

Paulgat .... 1 inch.
Dain...................... 4.277 yds.
Viss...................... 3.6 lbs.
Taim...................... 5.5 "
Saading.................. 22 "

Also same as England.

Canary Isles.

Onza.................... .927 inch.
Pic, Castilian .... 11.128 ins.
Almude .... .0416 acre.
Fanegada................ .5 "
Libra .... 1.0148 lbs.

Also same as Spain.

Cape of Good Hope.

Foot.................. 11.616 ins.
Morgen .... 2.116 54 acres.

Also same as in England.

Ceylon.

Seer .... 1 quart.
Parrah..................... 5.62 galls.

Also same as in England.

China.

Li .... .486 inch.
Chih, Engineer's......... 12.71 ins.
" or Covid.......... 13.125 "
" " legal...... 14.1 "
Chang .... 131.25 "
" legal............. 141 "
Pu...................... 4.05 ft.
Chang, fathom .... 10.9375 ft.
Li...................... 486 yds.
Pú or Kung .... 3.32 sq. yds.
King, 100 Mau........... 16.485 acres.
Tau.................... 1.13 galls.
Tael .... 1.333 oz.
Catty .... 1.333 lbs.

Cochin China.

Thuoc or Cubit........... 19.2 ins.
Sao...................... 64 sq. yds.
Mao .... 1.32 acres.
Hao...................... 6.222 galls.
Shita .... 12.444 "
Nen...................... .8594 lb.

Colombia and Venezuela.

Libra......... 1.102 lbs.
Oncha....... "

Also

Denmark,* Greenland, Iceland, and Norway.

Tomme	1.0297 ins
Fod	1.0297 ft.
Favn, 3 Alen	6.1783 "
Mil	4.680 55 miles.
" nautical	4.610 72 "
Anker	8.0709 galls.
Skoppe	.478 bush.
Fjerdingkar	.9558 "
Pund	1.1023 lbs.
Lispund	17.367 "
Centner	110.23 "

* *Also Decimal System.*

Ecuador.

Decimal System.

Genoa, Sardinia, and Turin.

Palmo	9.8076 ins.
Piede, Manual, 8 oncie	13.488 "
" Liprando, 12 "	20.23 "
Trabuco or Tesa	10.113 ft.
Miglio	1.3835 miles.
Starello	.9804 acre.
Giomaba	.9394 "

Germany.

The old measures of the different States differ very materially; generally, however,

Foot, Rhineland	12.357 ins.
Meile	4.603 miles.

Decimal System made compulsory in 1872.

Greece.

Stadium	.6155 mile.

Also Decimal System.

Guinea.

Jachtan	12 ft.

Hamburg.

Fuss	11.2788 ins.
Klafter	5.6413 ft.
Morgen	2.386 acres.
Cube Fuss	.8311 cub. ft.
Tehr	99.73 "
Viertel	1.594 7 galls.
Pfund (500 grammes)	1.102 32 lbs.
Ton	2135.8 lbs.

Also Decimal System.

Hanover.

Fuss	11.5 ins.
Morgen	.6476 acre.

Hindostan.

Borrel	1.211 ins.
Gerah	2.387 "
Haut	19.0[illegible] "
Kobe	"
Coss	
Tuda	
Candy	

Hungary.

Fuss	12.445 ins.
Elle	30.67 "
Meile	9.139 yds.

Also as in Vienna.

Indian Empire.

Guz	27.125 ins.
Cowrie	1 sq. yd.
Sen	61.025 39 cub. ins.
"	2.204 737 lbs.

Uniform standard of multiples of the Sen adopted in 1871.

Italy.

Milan and Venice.

Decimal System.

The Metre is termed Metra; the Are, Ara; the Stere, Stero; the Litre, Litro; the Gramme, Gramma, and the Tonneau, Tonnelata de Mare.

Naples and Two Sicilies.

Palmo	10.381 ins.
Canna	6.921 ft.
Miglio	1.1506 miles.
Migliago	.7467 acre.
Moggia	.86 "
Pezza, Roman	.6529 "

Roman States.

Old Measure.

Foot	11.592 ins.
" Architect's	11.73 "
Braccio	30.73 "
Palmo	8.347 "
Miglio	1628 yds.
Quarta	1.1414 acres.

Lucca and Tuscany.

Pie	11.94 ins.
Palmo	11.49 "
Braccio	22.98 "
Passetto	3.829 ft.
Passo	5.74 "
Miglio	1.0277 miles.
Quadrato	.8413 acre.
Saccato	1.324 "

Japan.

Sun,	.303 03 Metre	1.193* ins.
Shaku,	3.0303 Metres	11.9305* ins.
Jo,	30.303 "	9.9421* ft.
Ken,	5.5 "	5.9653* "
Ri,	11 880 "	2.4403 miles.
Kai-ri		6080 feet.†
Hiro		4.971* feet.
Momme		3.756 521 7 grammes Fr.
Hiyaku-me		.828 17 lbs.
Kwam-me		8.281 71 "
Hiyak-kin		132.507 32 "
Man's load		57.972 "
Koku		331.268 31 "
Hiyak-koku		33 126.830 8 "

[illegible] are as equivalent as they are practi- [illegible]

[illegible]

Java.

....	1.3 ins.
....	27.08 "
....	7.015 acres.
....	.328 galls.
....	593.6 grains.
....	61.034 lbs.
....	122.068 "
....	1.356 "

Madras.

....	10.46 ins.
....	18.6 "
....	33 "
....	20.92 ft.
....	3472 yds.
....	.338 galls.
....	2.704 "
....	180 grains.
....	.625 lbs.
....	3.086 "
....	24.686 "

Malabar.

....	10.46 ins.

Malacca.

l............	18.125 ins.
....	6 ft.
....	80 yds.

Malta.

....	10.3125 ins.
....	11.167 "
....	82.5 "
....	4.44 acres.

'so as in Sicily.

Moldavia.

....	8 ins.
....	24.86 ins.
....	8 ft.

ıoca Islands.

....	18.333 ins.

Morocco.

....	2.81025 ins.
....	20.34 ins.
....	21 "
....	3.08135 galls.
....	3.356 "
....	1.12 lbs.

than oil are sold by weight.

Mysore.

....	2.12 ins.
....	19.1 "
....	38.2 "
....	500 lbs.

etherlands.

....	39.370432 ins.

l System since 1817.

Persia.

....	2.375 ins.
....	25 "
....	37.5 "
Archin, Schah	31.55 ins.
" Arish............	38.27 "
Parasang............	6076 yds.
Chenica............	80.26 cub. ins.
Artaba............	1.809 bush.
Miscal............	71 grains.
Ratel............	2.1136 lbs.
Batman Maund............	6.49 "

Liquids are measured by weight.

Poland.

Trewice............	14.03 ins.
Precikow............	17 ins.
Pretow............	4.7245 yds.
Mile, short............	6075 yds.
Morgen............	1.3843 acres.

Portugal and Mozambique.

Foot............	13 ins.
Milha............	1.2788 miles.
Almude............	3.7 galls.
Fanga............	1.488 bush.
Alguieri............	3.6 "
Libra............	1.012 lbs.

Also Decimal System.

Prussia.

Fuss............	12.358 ins.
Ruthe............	4.1192 yds.
Meile............	24 000 feet.
Quadrat Fuss............	1.0603 sq. ft.
Morgen............	.63103 acre.
Cube Fuss............	1.092 cub. ft.
Scheffel............	1.5121 bush.
Anker............	7.559 galls.
Pound............	7217 grains.
Zollpfund............	1.1023 lbs.
Centner............	113.43 lbs.

Russia.

Vershok............	1.75 ins.
Foot............	12 ins.
Arschine............	28 "
Rhein Fuss............	1.03 ft.
Sajene............	7 ft.
Verst............	3500 "
Mila............	5.5574 miles.
Dessatina............	2.4954 acres.
Vedro............	2.7049 galls.
Tschel-werha............	1.4424 "
Pajak............	1.4426 bush.
Tschetwert............	5.7704 "
Pound............	6317 grains.
Funt............	.90285 lbs.

Decimal System adopted in 1872.

Siam.

K'up............	9.75 ins.
Covid............	18 ins.
Ken............	39 "
Jod............	.09848 mile.
Roëneng............	2.462 miles.

Silesia.

Fuss............	[illegible]
Ruthe............	
Meile............	
Morgen............	

Singapore.

Hasta or Cubit	18 ins.
Dessa	6 ft.
Orlong	80 yds.

Smyrna.

Pic	26.48 ins.
Indise	24.648 "
Berri	1828 yds.

Spain, Cuba, Malaga, Manilla, Guatemala, Honduras, and Mexico.

Pie	11.128 ins.
Vara	33.384 "
Milla	.865 mile.
Legua, 8000 varas	4.2151 miles.
Fanegada	1.6374 acres.
Vara, cubo	21.531 cub. ft.
Cuartilla	.888 gall.
Arroba, Castile	3.554 galls.
Fanega	1.5077 bush.
Libra	1.0144 lbs.
Tonelada	2028.2 lbs.

Also Decimal System.

Stettin.

Fuss	11.12 ins.
Foot, Rhineland	12.357 "
Elle	25.6 ins.
Morgen	1.5729 acres.

Sumatra.

Jankal or Span	9 ins.
Elle	18 "
Hailoh	36 "
Fathom	6 ft.
Tung	4 yds.

Surat.

Tussoo, cloth	1.161 ins.
Guz, "	27.864 "
Hath	20.9 "
Covid	18.5 "
Biggah	.51 acre.

Sweden.

Fot	11.6928 ins.
Ref	32.4703 yds.
Faden	5.845 ft.
League	3.3564 miles.
Meile	6.6417 "
Tunnland	1.2198 acres.
Anker	8.641 galls.
Spann	1.962 bush.
Centner	112.05 lbs.

Also Decimal System.

Switzerland.

Fuss, Berne	11.52 ins.
"	11.54 "
Vaud	11.81 "
Klafter	5.77 ft.
Meile	4.8568 miles.
Juchart, Berne	.85 acre.
Maas	2.6412 pints.
Eimer	8.918 galls.
Malter	4.1268 bush.
Pfund	1.1023 lbs.

Also Decimal System.

Tripoli.

Pik, 3 palmi	26.42 ins.
Almud	319.4 cub. ins.
Killow	2023 " "
Barile	14.267 galls.
Temer	.7383 bush.
Rottol	7680 grains.
Oke	2.8286 lbs.

Turkey.

Pic, great	27.9 ins.
" small	27.06 "
Berri	1.828 yds.
Alma	1.154 galls.

Also Decimal System.

Würtemberg.

Fuss	11.29 ins.
Elle	2.015 ft.
Meile	8146.25 yds.
Morgen	.7793 acre.
Cube Fuss	.83045 cub. ft.
Eimer	64.721 galls.
Scheffel	4.878 bush.
Pound	7217 grains.

Zurich.

Fuss	11.812 ins.
Elle	23.625 "
Klafter	5.9062 ft.
Meile	4.8568 miles.
Juchart	.808 acre.
Cube Klafter	144 cub. ft.

Holland.

Denominations corresponding to the French are as follows:

Length.—Millimetre, Streep; centimetre, Duim; decimetre, Palm; metre, El; decametre, Roede; kilometre, Mijle.

Surface.—Square millimetre, Vierkante Streep; square centimetre, Vierkante Duim; and so on. Hectare, Vierkante Bunder.

Cube Measure.—Millistere, Kubicke Streep, and so on.

Capacity.—Centilitre, Vingerhoed; decilitre, Maatje; liquid litre, Kan; dry litre, Kop; decalitre, Schepel; liquid hectolitre, Vat or Ton; dry hectolitre, Mud or Zak; 30 hectolitres = 1 Last = 10.323 quarters.

Weight.—Decigramme, K[illegible] gramme, Wigtje; decagramme, Lood; hectogramme; kilogramme [illegible]

[illegible]gium.

[illegible] .—The [illegible] substituted for kilogramme, Litron for litre, [illegible] litre.

SCRIPTURE AND ANCIENT LINEAR MEASURES.

Scripture.

.... .912 inch.	Span, 3 palms............... 10.944 ins.
40 digits............. 3.648 ins.	Cubit, 2 spans.............. 21.888 "

Fathom, 4 cubits............ 7 feet 3.552 ins.

Hebrew and Egyptian.

l cubit.............. 1.475 feet.	Babylonian foot............. 1.140 feet.
" .... 1.7216 "	Hebrew " .... 1.212 "
ian finger........... .06145 "	" cubit................ 1.817 "

Hebrew sacred cubit........... 2.002 feet.

Grecian.

.... .7554 inch.	Ancient Greek foot (16 Egyptian fingers) ..... .9841 foot.
foot)................. 1.0073 feet.	
.... 1.1332 "	Arabian foot............... 1.095 feet.
or natural foot...... .814 foot.	Stadium................. 604.0375 "
r Olympic " ...... 1.009 feet.	Olympic stadium......... 606.29 "

Mile, 8 stadium......... 4835 feet.

Alexandrian or Phileterian stadium (600 Phil. feet) = 708.65 feet.

Volume.—Keramion or Metretes.............. 8.488 gallons.

Jewish.

.... 1.824 feet.	Mile, 4000 cubits....... 7296 feet.
h day's journey.... 3648. "	Day's journey............ 33.164 miles.

Roman Long Measures.

.... .72575 ins.	Cubit...................... 1.4505 feet.
inch)............. .967 "	Passus..................... 4.835 "
t)................ 11.604 "	Mile, milliarium......... 4842 "

ANCIENT WEIGHTS.

Hebrew and Egyptian.

	Troy grains.		Troy grains.
olus..................	8.2* / 9.1†	Denarius, Roman............	51.9* / 62.5†
		" Nero..............	54‡
achma................	51.9* / 54.6† / 69‡	Shekel......................	92.62
ina..................	3.892	Ounce......................	415.1* / 437.2† / 431.2‡
mina.................	5.46		
1 mina............	8.326*	Drachm....................	146.5
ic "	8.985*	Libra......................	4086.1
rian "	9.992*	Pound................	12 Roman ounces.
....	4.63	Talub....................	581.71 ounces.

Talent (60 minæ).................... 56 lbs. avoirdupois.

Grecian.

	Troy grains.		Troy ounces.
ncient................	8.33	Mina........................	10.41
....	11.57	" great....................	14.472
....	23.15	Talent.......................	625.19
....	50.01	" Attic..................	868.32
great.................	69.47		

Roman.

.... 416.82 grains.	Pound................

---

* Christiani. † Arbuthnot. ‡ Pi

E*

GEOGRAPHIC MEASURES AND DISTANCES.

To Reduce Longitude into Time.

RULE.—Multiply degrees, minutes, and seconds by 4, and product is the time.

EXAMPLE.—Required time corresponding to 50° 31′. 50° 31′ × 4 = 3*h.* 22*m.* 4*s.*

To Reduce Time into Longitude.

RULE.—Reduce hours to minutes and seconds, divide by 4, and quotient is the longitude. *Or*, Multiply them by 15.

EXAMPLE.—Required longitude corresponding to 5*h.* 8*m.* 11.2*s.*

5*h.* 8*m.* 11.2*s.* = 308*m.* 11.2*s.*, which ÷ 4 = 77° 2′ 45.5″.

Or, multiplying by 15: 5*h.* 8*m.* 11.2*s.* × 15 = 77° 2′ 45.5″.

Table of Departures for a Distance run of 1 Mile.

Course.	Departure.	Course.	Departure.	Course.	Departure.
3.5 points.	.773	4.5 points.	.634	5.5 points.	.471
4 "	.707	5 "	.556	6 "	.383

Thus, if a vessel holds a course of 4 points, that is without leeway, for distance of 1 mile, she will make .707 of a mile to windward.

Or, a vessel sailing E.N.E. upon a course of 6 points for 100 miles will make 38.3 (100 × .383) miles of longitude.

Degrees, Minutes, and Seconds of each Point of the Compass with Meridian.

NORTH.	SOUTH.	Points.	° ′ ″	Sin. A.*	Cos. A.*	Tan. A.*
		.25	2 48 45	.0489	.9988	.0491
N.	S.	.5	5 37 30	.098	.9952	.0985
		.75	8 26 15	.1467	.9891	.1484
		1	11 15	.195	.9808	.1989
N. by E.	S. by E.	1.25	14 3 45	.2429	.97	.2504
N. by W.	S. by W.	1.5	16 52 30	.2903	.9569	.3034
		1.75	19 41 15	.3368	.9415	.3578
		2	22 30	.3827	.9239	.4142
N.N.E.	S.S.E.	2.25	25 18 45	.4275	.904	.4729
N.N.W.	S.S.W.	2.5	27 7 30	.4714	.8819	.5345
		2.75	30 56 15	.5141	.8577	.5994
		3	33 45	.5556	.8315	.6682
N.E. by N.	S.E. by S.	3.25	36 33 45	.5957	.8032	.7416
N.W. by N.	S.W. by S.	3.5	39 22 30	.6344	.773	.8207
		3.75	42 11 15	.6715	.7409	.9063
		4	45	.7071	.7071	1
N.E.	S.E.	4.25	47 48 45	.7404	.6715	1.103
N.W.	S.W.	4.5	50 37 30	.773	.6344	1.218
		4.75	53 26 15	.8032	.5957	1.348
		5	56 15	.8315	.5556	1.497
N.E. by E.	S.E. by E.	5.25	59 3 45	.8577	.5141	1.668
N.W. by W.	S.W. by W.	5.5	61 52 30	.8819	.4714	1.871
		5.75	64 41 15	.904	.4275	2.114
		6	67 30	.9239	.3827	2.414
E.N.E.	E.S.E.	6.25	70 18 45	.9415	.3368	2.795
W.N.W.	W.S.W.	6.5	73 7 30	.9569	.2903	3.296
		6.75	75 56 15	.97	.2429	3.941
		7	78 45	.9808	.195	5.027
E. by N.	E. by S.	7.25	81 33 45	.9891	.1467	6.741
W. by [illegible]	W. by S.	[illegible]	84 22 30	.9952	.098	10.153
		[illegible]	[illegible]7 11 15	.9988	.0489	20.555
[illegible] or West		[illegible]	[illegible]	1	.0000	∞

* A, repres[illegible] [illegible]nts from the meridian.

GEOGRAPHIC LEVELLING.

Curvature and Refraction.

rrection for Curvature of Earth, to be subtracted from reading of elling-staff, is determined as follows:

vide square of distance in feet from level to staff, by Earth's Equa. diameter—viz., 41 852 124 feet.

Two thirds of square of distance in statute miles equal the cure in feet.

rection for Refraction is to be subtracted from reading, and as a mean e taken at about one sixth of that for curvature.

rection for Curvature and Refraction combined, is to be added to ig on staff.

Formulas of Capt. T. J. Lee, U. S. Engineers.

= correction for curvature, $\frac{D^2}{R}$ *m = correction for refraction,* and

$2\,m)\frac{D^2}{2\,R}$ *= correction for curvature and refraction.* D *representing ce,* R *radius of earth, and m a coefficient of refraction* = .075, *all*

STRATION.—A distance is 3 statute miles, what is correction for curvature fraction?

$$(1-2\times.075)\frac{\overline{5280\times 3}^2}{41\,852\,124}=.85\times 5.996=5.097\ \textit{feet.}$$

oximately, $\frac{2}{3}$ D^2 *= curvature in feet.*

Levelling by Boiling Point of Water.

Compute Height Above or Below Level of Sea.

$$517\,(212^\circ-T)+(212^\circ-T)^2=\textit{Height.}$$

TRATION.—What is height of an elevation, when boiling point of water is 182°?

$$517\times\overline{212^\circ-182^\circ}+\overline{212^\circ-182^\circ}^2=517\times 30+30^2=16\,410\ \textit{feet.}$$

ctions for Temperature to be made in Connection with Formula.

orrection.	Temp.	Correction.	Temp.	Correction.	Temp.	Correction.	Temp.	Correction.	Temp.	Correction.
	°		°		°		°		°	
936	18	.972	36	1.008	54	1.046	72	1.083	90	1.12
94	20	.976	38	1.012	56	1.05	74	1.087	92	1.124
944	22	.98	40	1.016	58	1.054	76	1.091	94	1.128
948	24	.984	42	1.02	60	1.058	78	1.096	96	1.132
952	26	.988	44	1.024	62	1.062	80	1.1	98	1.136
956	28	.992	46	1.028	64	1.066	82	1.104	100	1.14
96	30	.996	48	1.032	66	1.071	84	1.108	102	1.144
964	32	1	50	1.036	68	1.075	86	1.1		1.148
968	34	1.004	52	1.041	70	1.079	88	1.[illegible]		[illegible]

ATION.—Assume temperature in preceding illustration

Then 16 410 × 1.1 = 18 051 *feet.*

Apparent Level of Objects at or upon Surface of Land or Sea, and Differences between True and Apparent Levels, Curvatures, etc.

Distances in Geographic or Nautical Miles.

	HEIGHT of Line of Sight.	HEIGHT of Curvature above Land.	HEIGHT of Curvature and Refraction. Land.	HEIGHT of Curvature and Refraction. Sea.	Apparent Level including Curvature and Refraction. Land.	Apparent Level including Curvature and Refraction. Sea.	Distance.	HEIGHT of Line of Sight.	HEIGHT of Curvature above Land.	HEIGHT of Curvature and Refraction. Land.	HEIGHT of Curvature and Refraction. Sea.	Apparent Level including Curvature and Refraction. Land.	Apparent Level including Curvature and Refraction. Sea.
	Feet.	Feet.	Feet.	Feet.	Miles.	Miles.	Miles.	Feet.	Feet.	Feet.	Feet.	Miles.	Miles.
	.667	.662	.563	.568	1.09	1.08	7.24	35	34.7	29.51	29.77	7.89	7.85
	1	.99	.835	.842	1.33	1.32	7.74	40	39.66	33.73	34.02	8.43	8.39
	2	1.98	1.69	1.7	1.89	1.88	8.21	45	44.62	37.95	38.28	8.94	8.9
	3	2.98	2.53	2.55	2.31	2.29	8.66	50	49.65	42.21	42.59	9.43	9.38
	4	3.97	3.38	3.41	2.67	2.65	9.08	55	54.58	46.42	46.83	9.89	9.83
	5	4.97	4.23	4.26	2.98	2.97	9.48	60	59.48	50.59	51.04	10.33	10.24
	6	5.96	5.07	5.1	3.27	3.25	10.24	70	69.42	59.03	59.56	11.16	11.1
	7	6.95	5.91	5.96	3.53	3.51	10.95	80	79.37	67.5	68.1	11.93	11.86
	8	7.93	6.74	6.8	3.77	3.75	11.61	90	89.23	75.89	76.56	12.65	12.59
	9	8.92	7.58	7.65	4	3.98	12.24	100	99.18	84.35	85.1	13.33	13.27
	10	9.91	8.43	8.51	4.22	4.19	14.99	150	148.7	126.51	127.63	16.33	16.25
[illegible]	11	10.91	9.28	9.36	4.42	4.4	17.31	200	198.4	168.7	170.2	18.86	18.77
4.24	12	11.9	10.12	10.21	4.62	4.59	21.2	300	297.6	253.03	255.28	23.09	22.98
4.41	13	12.87	10.95	11.05	4.81	4.78	24.49	400	397	337.66	340.66	26.67	26.54
4.58	14	13.89	11.81	11.91	4.99	4.96	27.37	500	495	421.75	425.5	29.81	29.67
4.74	15	14.87	12.65	12.76	5.16	5.14	29.99	600	595.4	506.36	510.86	32.65	32.51
4.9	16	15.89	13.52	13.64	5.33	5.3	32.39	700	694.5	590.65	595.89	35.28	35.11
5.04	17	16.82	14.3	14.43	5.5	5.46	34.63	800	793.9	675.17	681.17	37.71	37.53
5.19	18	17.83	15.16	15.3	5.66	5.62	36.73	900	893.1	756.16	768.87	40	39.8
5.33	19	18.81	15.99	16.14	5.81	5.78	38.72	1000	992.5	844.07	851.57	42.23	41.96
5.48	20	19.88	16.91	17.06	5.96	5.93	54.76	2000	1985	1688.3	1703.2	59.63	59.34
5.61	21	20.83	17.72	17.87	6.11	6.08	67.06	3000	2977	2531.8	2544.3	73.03	72.68
5.74	22	21.81	18.55	18.72	6.25	6.22	77.44	4000	3970	3376.3	3406.3	84.32	83.92
5.87	23	22.81	19.4	19.57	6.39	6.36	86.58	5000	4962	4220.3	4257.8	94.28	93.83
5.98	24	23.67	20.13	20.31	6.53	6.5	95.52	1 Mile.	6040	5136.9	5182.5	104.03	103.54
6.12	25	24.79	21.08	21.27	6.67	6.63	135.09	2 Miles.	12081	10274	10366	147.1	146.39
6.7	30	29.72	25.27	25.5	7.3	7.26	165.44	3 "	18119	15430	15546	180.16	179.3

NOTE 1.—Height or elevation in second column of table is also curvature of Earth at Ocean.
2. Refraction is greater and more variable at sunrise and sunset, and comparatively stationary between hours of 10 A.M. and 4 P.M.

STRATION. — Curvature of Earth independent of refraction is computed at oot = 8.004 ins. for 1 geographical mile, and as refraction on land is taken as oot or 1.248 ins., and on ocean at .099 foot or 1.188 ins., relative visible dis- of an object, including curvature and refraction, for an elevation of

.667	foot	is	1.09	miles on land, and	1.08 miles at sea.
1	"	"	1.33	" " " "	1.32 " " "
9	feet	"	4	" " " "	3.98 " " "
1	mile	"	104.03	" " " "	103.54 " " "

ference between two levels in feet is as square of their distance in

STRATION. — At what elevation can an object be seen, at surface of ocean, when miles distant?

$1^2 : 2^2 :: .568 : 2.272$ *feet* $= 2$ *feet* $3.25+$ *ins.*

erence between two distances in miles is as square root of their heights

STRATION 1. — At an elevation of 9 feet above level of sea, at what distance object be seen upon its surface?

$\sqrt{.568} = .754 : 1 :: \sqrt{9} : 3.98$ *miles.*

f a man at the fore-topgallant mast-head of a vessel, 100 feet from water, sees r and a large vessel "hull to," how far are the vessels apart?

ge vessel's bulwarks are at least 20 feet from water.

m, by table, 100 feet................= 13.27
20 " ....= 5.93
Distance........ 19.20 *miles.*

en an observation for distance is taken from an elevation, as from -house, a vessel's mast, etc., of an object that intervenes between er and horizon, or contrariwise, observer being at a horizon to d object, distance of observer from intervening object can be ined by ascertaining or estimating its elevation from horizon, and cting its distance from whole distance between observer and rom which observation is taken, and remainder will give distance ct from observer.

TRATION. — Top of smoke-pipe of a steamer, assumed to be 50 feet above sur- water, is in range with horizon from an elevation of 100 feet; what is dis- steamer from elevation?

100 feet....................= 13.27
50 " ....= 9.38
Distance........ 3.89 *miles.*

ximately.—Curvature less Refraction = .566 D^2 for land and .563 D^2 for sea *nting distance in miles.*

MAGNETIC VARIATION OF NEEDLE.

ica. — Needle reached a Westerly maximum in 1660, and then o East until 1800, when it reversed to West.

n (Eng.). — From 1576 to 1815 variation ranged from 11° 15′ 24° 27′ West, when it receded gradually to 21° in 1865.

ica (W. I.).—No variation from year 1660.

al Variation.—There is a small diurnal variation, being greatest *ier* (15′), *and least in* winter (7′ 30″), added to which a *ature affects a needle.*

Variation in U. S.—Professor Loomis concludes that the Westerl variation is increasing and Easterly diminishing in every part of Unite States; that this change occurred between 1793 and 1819, and tha present annual change is about 2′ in Southern and Western States, from 3′ to 4′ in Middle States, and 5′ to 7′ in Eastern States.

Rules for computation of variation are empirical, except in eac particular locality, as the annual and diurnal variations of the needle added to local attraction, render it altogether unreliable.

Decennial Variation of Needle.

Mr. Schott, U. S. Coast and Geodetic Survey.

From January 1, 1790, to January 1, 1880.

LOCATION.	1790.	1800.	1810.	1820.	1830.	1840.	1850.	1860.	1870.	188
	W. °	W. °	W. °	W. °	W. °	W. °	W. °	W. °	W. °	W °
Halifax, N. S.	15.1	15.9	16.7	17.4	18.1	18.7	19.3	19.8	20.1	20.
Quebec, Can......	—	—	11.2	12.3	13.4	14.4	15.3	16	16.4	—
Portland, Me.	8.5	8.9	9.4	10	10.6	11.23	11.82	12.35	12.8	13.
Burlington, Vt....	7.7	7.52	7.39	7.58	8.17	8.94	9.62	10.21	10.97	11.
Newburyport, M's.	7.2	7.4	7.8	8.4	9	9.6	10.23	10.83	11.4	11.
Portsmouth, N. H.	7.8	8	8.4	8.8	9.35	9.94	10.55	11.15	11.7	12.
Rutland, Vt.	6.5	6.2	6.14	6.39	6.9	7.64	8.53	9.53	10.54	11.
Salem, Mass......	6.2	6.2	6.5	7	7.8	8.7	9.8	10.9	11.9	12.
Boston, Mass.	6.7	7	7.4	7.9	8.43	9.05	9.69	10.32	10.9	11.
Cambridge, Mass..	6.9	7.1	7.5	8	8.64	9.33	10.03	10.67	11.21	11.
Providence, R. I. .	6.24	6.37	6.45	6.73	7.43	8.31	9.09	9.65	10.21	10.
Hartford, Conn. ..	5.2	5.16	5.24	5.46	5.8	6.24	6.77	7.36	7.99	8.
New Haven, Conn.	4.8	4.7	4.8	5	5.43	5.99	6.67	7.41	8.18	8.
New York, N. Y. .	4.29	4.28	4.3	4.47	4.91	5.59	6.34	6.96	7.43	7.
Philadelphia, Pa..	2.4	2.1	2.1	2.28	2.71	3.33	4.11	4.99	5.89	6.
Baltimore, Md....	—	—	.6	.8	1.2	1.7	2.4	2.9	—	—
Albany, N. Y.	—	— E.	5.4	5.79	6.32	6.97	7.7	8.47	9.2	9
Buffalo, N. Y.	.14 E.	.01	.05 E.	.3 E.	.74 E.	1.33	2.05	2.85	3.68	4
Erie, Pa..........	.03	.35	.49	.43	.17	.25 E.	.83 E.	1.5	2.23	2
Cleveland, O......	2.2	2	1.8	1.5	1.05	.6	.14	.31 E.	.72 E.	1
Detroit, Mich.....	—	3.18 W.	3.11 W.	2.9 W.	2.55 W.	2.09 W.	1.56 W.	.99 W.	.41 W.	
Washington, D. C.	.1	— E.	.3 E.	.6 E.	1 E.	1.49 E.	1.99 E.	2.47 E.	2.9 E.	3
Acapulco, Mex....	7.2	7.8	8.3	8.68	8.88	8.91	8.79	8.5	8.06	7
Charleston, S. C...	5.1	4.9	4.5	4.04	3.44	2.78	2.12	1.52	1	
Havana, Cuba....	—	6.2	6.26	6.22	6.12	5.94	5.71	5.44	5.1	-
Kingston, W. I....	6.3	6	5.7	5.4	5	4.6	4.2	3.8	3.4	-
San Diego, Cal....	11	11.1	11.3	11.6	11.9	12.2	12.54	12.88	13.2	13
Savannah, Ga.....	—	—	4.9	4.8	4.5	4.14	3.65	3.08	2.48	1
Mobile, Ala.......	—	7.1	7.2	7.3	7.2	7.1	7	8.8	—	6
Key West, Fla....	—	—	—	6.9	6.52	6.03	5.47	4.86	4.24	3
Monterey, Cal. ...	11.4	12	12.6	13.3	13.9	14.44	14.95	15.42	15.79	16
Mexico, Mex......	7.1	7.7	8.3	8.6	8.8	8.9	8.76	8.48	8.04	7
New Orleans, La..	7	7.5	7.9	8.1	8.2	8.14	7.94	7.61	7.15	6
San Blas, Mex. ...	7.41	7.88	8.28	8.61	8.84	8.97	9.9	8.91	—	-
San Francisco, Cal.	12.8	13.4	13.9	14.42	14.92	15.38	15.78	16.11	16.36	16
Sitka, Alaska.....	—	26.12	27.11	27.89	28.48	28.88	29.08	29.08	28.88	28
Vera Cruz, Mex...	8.37	8.95	9.32	9.48	9.42	9.14	8.66	7.98	7.15	-

For variation in other locations in United States and North Ameri *see Treatises of J. B.* Stone, C.E., New York, and Heller and Brigh *Philadelphia, 1878.*

:or Reducing Observed Daily Variation of Needle to Mean Variation of the Day.

U. S. Coast and Geodetic Survey, 1878.

· s.	Needle East of Mean Magnetic Meridian.					Needle West of Mean Magnetic Meridian.							
	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	NOON.	P.M.	P.M.	P.M.	P.M.	P.M.	P.M.
	h. 6 ′	h. 7 ′	h. 8 ′	h. 9 ′	h. 10 ′	h. 11 ′	Noon. ′	h. 1 ′	h. 2 ′	h. 3 ′	h. 4 ′	h. 5 ′	h. 6 ′
......	3	4	4	3	1	1	4	5	5	4	3	2	1
......	4	5	5	4	1	2	4	6	5	4	3	2	1
......	2	3	3	2	—	2	3	4	3	2	1	1	—
......	1	1	2	2	1	—	2	3	5	2	1	1	—

.on of Needle at Locations in United States and Canada, 1875.

U. S. Coast and Geodetic Survey.

EAST.

Location.	Variation.		Location.	Variation.	
	°	′		°	′
. T.	21	30	Montgomery, Ala.	5	2
a.	2	28	Natchez, Miss.	7	26
x.	9	15	Nebraska, Neb.	11	20
Dak.	16	6	New Orleans, La.	6	50
l.	5		Olympia, W. T.	22	8
, O.	2	55	Omaha, Neb.	11	
prings, Col.	14	18	Oregon City, Or.	20	55
S. C.	1	45	Paducah, Kan.	6	2
O.	1	8	Portland, Or.	21	4
, Dak.	16	20	Port Townsend, W. T.	23	
ol.	14	45	Sacramento, Cal.	17	4
ich.		3	Salt Lake City, Utah	17	
in.	10	12	San Antonio, Tex.	9	17
Tex.	8	13	Santa Barbara, "	14	58
, Wis.	6		Santa Fé, N. Mex.	13	18
ex.	27		Springfield, Ill.	6	3
lis, Ind.	3	38	St. Augustine, Fla.	2	55
liss.	7		St. Louis, Mo.	6	30
lle, Fla.	3		St. Paul, Minn.	10	30
an.	9	20	Tallahassee, Fla.	4	14
a.	7	55	Toledo, O.	1	2
k, Ark.	8	5	Topeka, Kan.	10	12
, Ky.	4		Vincennes, Ind.	5	
s, Wis.	5	48	Yazoo, Miss.	7	2

WEST.

Me.	14	34	Newburgh, N. Y.	8	
e.	16		Newport, R. I.	10	4
. Y.	4	40	Norfolk, Va.	2	35
e.	15	22	Ogdensburgh, N. Y.	9	25
t, Conn.	8	12	Oswego, N. Y.	6	8
. ...	18		Ottawa, Can.	9	38
N. H.	11	42	Pittsburgh, Pa.	1	28
l.	4	12	Raleigh, N. C.		24
r, Mass.	10	30	Richmond, Va.	1	48
, Can.	2	55	Rochester, N. Y.	5	20
g, Pa.	4	18	Saratoga, N. Y.	9	40
. Y.	8	48	Stamford, Conn.	8	
, Me.	14		Syracuse, N. Y.	7	
ass.	11	15	Toronto, Can.	3	50
r, Vt.	12	5	Trenton, N. J.	6	8
Can.	12	20	Troy, N. Y.	9	25
ord, Mass.	10	30	Utica, N. Y.	8	
on, Conn.	9	15	Wilmington, Del.	4	52
J.	7	18	Wilmington, N. C.		[illegible]

Dip of Horizon.

Approximate, $57.4\sqrt{H} =$ *dip in seconds*, varying with temperature of air. H *representing height of observer's eye in feet.*

$.667\,n^2 = H$: $.498\,s^2 = H$: $1.42\sqrt{H} = s$: $1.23\sqrt{H} = n$.
n representing distance in geographical miles and s in statute.

Measurement of Heights with a Sextant.

Multiplier.	Angle.	Multiplier.	Angle.	Multiplier.	Angle.	Multiplier.	Angle.	Multiplier.	Angle.
	° ′		° ′		° ′		° ′		° ′
1	45 0	2.5	68 11	4	75 58	5.5	79 42	8	82 52
1.5	56 18	3	71 34	4.5	77 29	6	80 32	9	83 40
2	63 26	3.5	74 4	5	78 41	7	81 52	10	84 17

Operation.—Set sextant to any angle in table, and height will equal distance multiplied by number opposite to it.

Illustration.—When sextant is set at 80° 32′, and horizontal distance from object in a vertical line is 100 feet, what is its height?

$$100 \times 6 = 600 \textit{ feet.}$$

By Trigonometry: 1 : 100 :: 5.997 (*tan.* angle) : 599.7 *feet.*

To Reduce a Sounding to Low Water.

$\frac{h}{2}\left(1 \mp \cos.\frac{180\,t'}{t}\right) = h'$. *h representing vertical rise of tide, and h′ sounding or depth at low water, both in feet; t time between high and low water, and t′ time from time of sounding to low water, in hours.* — *cos. when* $\frac{180\,t'}{t} < 90°$, *and* + *cos. when* $> 90°$.

Illustration.—Low water occurring at 3.45, and high water at 10.15 P.M., a sounding taken at 5.30 P.M. was 18.25 feet; what was depth at low water, vertical rise being 10 feet?

$$h = 10 \textit{ feet};\ t' = 5h.\ 30m. - 3h.\ 45m. = 1h.\ 45m. = 1.75 \textit{ hours}.$$
$$t = 10h.\ 15m. - 3h.\ 45m. = 6h.\ 30m. = 6.5 \textit{ hours}.$$

Then $\frac{10}{2}\left(1 \mp \cos.\frac{180 \times 1.75}{6.5}\right) = 5\,(1 - \cos.\ 48°\ 27'\ 41'') = 5 \times (1 - .663\,124) = 1.68438$ *feet.*

Sounding 18.25 *feet* — Reduction 1.68407 *feet* = 16.56593 *feet.*

Lengths of a Degree of Longitude on parallels of Latitude, for each of its Degrees from Equator to Pole.

Lat.	Miles.	Lat.	Miles.	Lat.	Miles.	Lat.	Miles.	Lat.	Miles.	Lat.	Miles.
1°	59.99	16°	57.67	31°	51.43	46°	41.68	61°	29.09	76°	14.52
2	59.96	17	57.38	32	50.88	47	40.92	62	28.17	77	13.5
3	59.92	18	57.06	33	50.32	48	40.15	63	27.74	78	12.48
4	59.85	19	56.73	34	49.74	49	39.36	64	26.3	79	11.45
5	59.77	20	56.38	35	49.15	50	38.57	65	25.36	80	10.42
6	59.67	21	56.01	36	48.54	51	37.76	66	24.4	81	9.38
7	59.55	22	55.63	37	47.92	52	36.94	67	23.44	82	8.35
8	59.42	23	55.23	38	47.28	53	36.11	68	22.48	83	7.31
9	59.26	24	54.81	39	46.63	54	35.27	69	21.5	84	6.27
10	59.09	25	54.38	40	45.96	55	34.41	70	20.52	85	5.23
11	58.89	26	53.93	41	45.28	56	33.45	71	19.53	86	4.18
12	58.69	27	53.46	42	44.59	57	32.68	72	18.54	87	3.14
13	58.46	28	52.97	43	43.88	58	31.79	73	17.54	88	2
14	58.22	29	52.48	44	43.16	59	30.9	74	16.54	89	1.05
15	57.95	30	51.96	45	42.43	60	30	75	15.53	90	.00

Note.—*Degrees of* longitude as Cosines of their *latitudes.*

Elements of Figure of the Earth.

Capt. A. R. Clarke, 1866.

	Feet.	Miles.
r semi-axis of Equator (longitude 15° 34′ E.)	20 926 350	3 963.324.
r " " " " (" 105° 34′ E.)	20 919 972	3 962.115.
" "	20 853 429	3 949.513.
torial semi-axis	20 926 062	3 963.269.
mference, mean	—	24 898.562.
eter, "	—	7 916.

BOARD AND TIMBER MEASURE.

BOARD MEASURE.

Board Measure, all boards are assumed to be 1 inch in thickness.

To Compute Measure or Surface.

When all Dimensions are in Feet.

.E.—Multiply length by breadth, and product will give surface in feet.

When either of Dimensions are in Inches.

PLE. — What are number of square feet in a board 15 feet in length and 16 n width?

$15 \times 16 = 240$, and $240 \div 12 = 20$ *sq. feet.*

When all Dimensions are in Inches.

E.—Multiply as before, and divide product by 144.

TIMBER MEASURE.

To Compute Volume of Round Timber.

When all Dimensions are in Feet.

.—Add together squares of diameters of greater and lesser ends, duct of the two diameters; multiply sum by .7854, and product third of length.

$+ a' + a'' \times \frac{l}{3} = V$, and $c^2 + c'^2 + \overline{c \times c'} \times .07958 \times \frac{l}{3} = V$. *a and enting areas of ends, a″ area of mean proportional, l length, and c rcumference of ends.*

-Mean proportional is square root of product of areas of both ends.

ATION.—Diameters of a log are 2 and 1.5 feet, and length 15 feet.

$^2 + 1.5^2 + \overline{2 \times 1.5}) = 9.25$, which $\times .7854$ and $\frac{15}{3} = 36.3245$ *cube feet.*

ien Length in Feet, and Areas or Circumferences in Inches.

—Proceed as above, and divide by 144.

When all Dimensions are in Inches.

—Proceed as before, and divide by 1728.

· Ordinary rule of Hutton, Ordnance Manual of U. S., and Molesworth, gives a result of about .25 less than exact volume or what it would be was hewn or sawed to a square. c representin mferences.

To Compute Volume of Squared Timber.

When all Dimensions are in Feet.

RULE.—Multiply product of breadth by depth, by length, and product will give volume in cube feet.

When either Dimension is in Inches.

RULE.—Multiply as above, and divide product by 12.

When any two Dimensions are in Inches.

RULE.—Multiply as before, and divide by 144.

EXAMPLE.—A piece of timber is 15 inches square, and 20 feet in length; required its volume in cube feet.

$$\frac{15 \times 15 \times 20}{144} = 31.25 \textit{ cube feet.}$$

Allowance is to be made for bark, by deducting from each girth from .5 inch in logs with thin bark, to 2 inches in logs with thick bark.

Measures of Timber.—(*English.*)

100 superficial feet of planking = 1 square.	50 cube feet of squared timber = 1 load.
120 deals .... = 1 hundred.	40 feet of unhewn timber = 1 load.

600 superficial feet of inch planking = 1 load.

Deals.

Deals.—Boards exceeding 7 ins. in width, and if less than 6 feet in length, are termed deal ends.

Battens are similar to deals, but only 7 inches in width.

Balk.—Roughly squared log or trunk of a tree.

Planks are boards 12 ins. in width.

Local Standards.

Country.	Long.	Broad.	Thick.	Volume.	Country.	Long.	Broad.	Thick.	Volume.
	Ft.	Ins.	Ins.	Cub. ft.		Ft.	Ins.	Ins.	Cub. ft.
Russia and Prussia..	12	11	1.5	1.375	Norway ..	12	9	3	2.25
Sweden...	14	9	3	2.625	Christiana	11	9	1.25	.859
					Quebec...	12	11	2.5	2.292

100 Petersburgh standard deals equal 60 Quebec deals.

SPARS AND POLES.

Pine and *Spruce Spars*, from 10 to 4.5 inches in diameter inclusive, are to be measured by taking their diameter, clear of bark, at one third of their length from abut or large end.

Spars are usually purchased by the inch diameter; all under 4 inches are termed *Poles*.

Spars of 7 inches and less should have 5 feet in length for every inch of diameter, and those above 7 inches should have 4 feet in length for every inch of diameter.

Loss or Waste in Hewing or Sawing of Timber.

(*C. Mackrow.*)

Oak, English .... 200 per cent.	Yellow Pine from planks.. 10 per cent.
" *African* 100 " "	Teak.................... 15 " "
" *Dantz* [illegible] " "	Elm, English .... 200 " "
" *Amer* " "	" American .... 15 " "

CISTERNS.

›acity of Cisterns in Cube Feet and Gallons.

For each 10 *Inches in Depth.*

ı.	Cub. ft.	Gallons.	Diam.	Cub. ft.	Gallons.	Diam.	Cub. ft.	Gallons.
			Feet.			Feet.		
	2.618	19.58	9.5	59.068	441.8	17	189.15	1414.94
	4.091	30.6	10	65.449	489.6	17.5	200.432	1499.33
	5.89	44.07	10.5	72.158	539.78	18	212.056	1586.28
	8.018	59.97	11	79.194	592.4	19	236.274	1767.45
	10.472	78.33	11.5	86.558	647.5	20	261.797	1958.3
	13.254	99.14	12	94.248	705	21	288.632	2159.11
	16.362	122.4	12.5	102.265	764.99	22	316.776	2369.64
	19.798	148.1	13	110.61	827.4	23	346.23	2589.97
	23.562	176.24	13.5	119.282	892.29	24	376.992	2820.09
	27.652	206.84	14	128.281	959.6	25	409.062	3059.8
	32.07	239.88	14.5	137.608	1029.38	26	442.44	3309.67
	36.816	275.4	15	147.262	1101.6	27	471.13	3569.17
	41.888	313.33	15.5	157.243	1176.26	28	513.126	3838.44
	47.288	353.72	16	167.552	1253.37	29	550.432	4117.51
	53.014	396.55	16.5	178.187	1332.93	30	589.048	4406.08

Excavation and Lining of Wells or Cisterns.

For each 10 *Inches in Depth.*

Excavation.	Bricks.		Masonry.		Diameter.	Excavation.	Bricks.		Masonry.	
	Number.	Laid dry.	8 inches thick.	1 foot thick.			Number.	Laid dry.	8 inches thick.	1 foot thick.
Cub. ft.		Cub. ft.	Cub. ft.	Cub. ft.	Feet.	Cub. ft.		Cub. ft.	Cub. ft.	Cub. ft.
12.29	126	5.24	6.4	10.47	8.5	63.29	356	14.83	16	24.87
15.29	147	6.11	7.27	11.78	9	69.89	377	15.71	16.87	26.18
18.62	168	6.98	8.14	13.09	9.5	76.81	398	16.58	17.75	27.49
22.27	188	7.85	9.02	14.4	10	84.07	419	17.45	18.62	28.8
26.25	209	8.73	9.89	15.71	10.5	91.65	440	18.33	19.49	30.11
30.56	230	9.6	10.76	17.02	11	99.56	461	19.2	20.36	31.42
35.2	251	10.47	11.64	18.33	12	116.36	503	20.94	22.11	34.03
40.16	272	11.34	12.51	19.63	13	134.46	545	22.69	23.85	36.65
45.45	293	12.22	13.38	20.94	14	153.88	586	24.43	25.6	39.27
51.07	314	13.09	14.25	22.25	15	174.61	628	26.18	27.34	41.89
57.02	335	13.96	15.13	23.56	16	196.64	670	27.92	29.09	44.51

ber of bricks and width of curb are taken at dimensions of ordinary viz., 8 by 4 by 2.25 ins. = 72 cube ins.

mputing number of bricks required, an addition of 5 per cent. should l for waste. It is to be considered, also, that diameter of excavation ·ily exceeds that of masonry.

SHINGLES.

lly of white Cedar and Cypress; 27 inches in length and 6 to 7 in width, dressed to light .25 inch at point and .3125 inch at

in three thicknesses and courses of about 8 inches. \ess
› of a shingle is exposed to air, or about 2.25 shi re-
›er square foot of roof.

les, alike to Slates, are laid upon boards or batter

SLATES AND SLATING.

A *Square* of Slate or Slating is 100 superficial feet.

Gauge is distance between the courses of the slates.

Lap is distance which each slate overlaps the slate lengthwise next but one below it, and it varies from 2 to 4 inches. Standard is assumed to be 3 inches.

Margin is width of course exposed or distance between tails of the slates.

Pitch of a slate roof should not be less than 1 in height to 4 of length.

To Compute Surface of a Slate when laid, and Number of Squares of Slating.

Rule.—Subtract lap from length* of slate, and half remainder will give length of surface exposed, which, when multiplied by width of slate, will give surface required.

Divide 14400 (area of a square in inches) by surface thus obtained, and quotient will give number of slates required for a square.

Example.—A slate is 24 × 12 inches, and lap is 3 inches; what will be number required for a square?

24 − 3 = 21, and 21 ÷ 2 = 10.5, which × 12 = 126 *inches;* and 14400 ÷ 126 = 114.29 *slates.*

Dimensions of Slates.

[American.]

Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
14 × 7	14 × 10	16 × 10	18 × 11	20 × 11	22 × 12	24 × 13
14 × 8	16 × 8	18 × 9	18 × 12	20 × 12	22 × 13	24 × 14
14 × 9	16 × 9	18 × 10	20 × 10	22 × 11	24 × 12	24 × 16

English.

	Ins.		Ins.		Ins.
Doubles	13×10	Ladies	12× 8	Marchioness ..	22×22
"	13× 7		14× 8	Duchess	24×12
Small doubles .	11× 6		14×12	Imperial	30×24
"	10× 5		15× 8	Rags	36×24
Plantations..	12×10		16× 8	Queens	36×24
	13×10		16×10	Empress	26×15
Viscountess ...	18×10	Countess	20×10	Princess	24×14

Thickness of slates ranges from .125 to .3125 of an inch, and their weight varies from 2 to 4.53 lbs. per sq. foot.

Weight of One Square Foot of Slating.

.125 in. thick on laths........	4.75 lbs.	.25 in. thick on laths........	9.25 lbs.
" " " " 1 in. boards..	6.75 "	" " " " 1 in. boards..	11.25 "
.1875 in. thick on laths.......	7 "	.3125 in. thick on laths......	11.15 "
" " " " 1 in. boards.	9 "	" " " " 1 in. boards,	14.10 "

Slate weighs from 167 to 181 lbs. per cube foot, and in consequence of laps, it requires an average of nearly 2.5 square feet of slate to make one of slating.

Weights per 1000 and Number Required to Cover a Square.

			No.			Lbs.	No.
Doubles	1?		180	Countess ...	20 × 10	6720	171
Ladies	1			Duchess ...	24 × 12	4480	125

n nail-hole to tail.

PILING OF SHOT AND SHELLS.

To Compute Number of Shot.

Triangular Pile. RULE.—Multiply continually together, number of shot in one side of bottom course, and that number increased by 1, and again by 2, and one sixth of product will give number.

EXAMPLE.—What is number of shot in a triangular pile, each side of base containing 30 shot?

$$\frac{30 \times \overline{30+1} \times \overline{30+2}}{6} = \frac{29760}{6} = 4960 \textit{ shot.}$$

Square Pile. RULE.—Multiply continually together, number in one side of bottom course, and that number increased by 1, double same number increased by 1, and one sixth of product will give number.

EXAMPLE.—How many shells are there in a square pile of 30 courses?

$$\frac{30 \times \overline{30+1} \times \overline{30 \times 2+1}}{6} = \frac{56730}{6} = 9455 \textit{ shells.}$$

Oblong Pile. RULE.—From 3 times number in length of base course subtract one less than number in breadth of it; multiply remainder by number in breadth, and again by breadth, increased by 1, and one sixth of product will give number.

EXAMPLE.—Required number of shells in an oblong pile, numbers in base course being 16 and 7?

$$\frac{16 \times 3 - \overline{7-1} \times 7 \times \overline{7+1}}{6} = \frac{2352}{6} = 392 \textit{ shells.}$$

Incomplete Pile. RULE.—From number in pile, considered as complete, subtract number conceived to be in that portion of pile which is wanting, and remainder will give number.

FRAUDULENT BALANCES.

To Detect Them.—After an equilibrium has been established between weight and article weighed, transpose them, and weight will preponderate if article weighed is lighter than weight, and contrariwise if it is heavier.

To Ascertain True Weight. RULE.—Ascertain weight which will produce equilibrium after article to be weighed and weight have been transposed; reduce these weights to same denomination, multiply them together, and square root of their product will give true weight.

EXAMPLE.—If first weight is 32 lbs., and second, or weight of equilibrium after transposition, is 24 lbs. 8 oz., what is true weight?

24 lbs. 8 oz. = 24.5 lbs.

Then $32 \times 24.5 = 784$, and $\sqrt{784} = 28$ lbs.

Or, when *a represents longest arm*, *b* " *shortest arm*, | A *greatest weight*, and B *least weight*.

Then $Wa = Ab$, and $Wb = Ba$; multiplying these two equations, $W^2ab = ABab$, or $W^2 = AB$, and $W = \sqrt{AB}$.

ILLUSTRATION.—$A = 32$; $B = 24.5$; $W = 28$. Assume length of longest arm = 10.

Then $32 : 28 :: 10 : 8.75$.

Hence, $a = 10$, $b = 8.75$, or $28^2 = 32 \times 24.5$, and $\sqrt{32 \times 24.5} = 28$.

Weighing without Scales.

To Ascert Weight of a Bar, Beam, etc., by Aid of a known Weight.

OPERATION ance bar, etc., over a fulcrum, and note distance between it and end of gest arm. Suspend a known weight from longest arm, and move bar pon fulcrum, so that bar with attached weight will be in equilibrio; ct distance between the two positions of fulcrum from longest arm t tained; multiply this remainder by weight suspended, divide produc stance between fulcrums, and quotient will give weight.

EXAMPLE.—A p f tapered timber 24 feet in length is balanced over a fulcrum when 13 feet fro end; but when the body of a man weighing 210 lbs. is suspended from of longest arm, the piece and weight are balanced when fulcrum is 12 fe is end. What is weight of the timber?

13—12— nd 13—1 = 12 *feet.* Then 12 × 210 ÷ 1 = 2520 *lbs.*

1 pound of pai yards for a first coat and about 6 yards for eacl

Proportions olors r Paints.—By Weight.

COLORS.	White Lead.	Lamp-black.	Red Lead.	Red Ochre.	
White......	100	—	—	—	—
Black.......	—	100	—	—	—
Green......	25	—	—	—	75

COLORS.	White Lead.	Lamp-black.	Red Lead.	Red Ochre.	Verdigris.	Spanish Brown.
.....	98	2	—	—	—	—
.....	—	—	50	50	—	—
late..	—	4	—	—	—	96

These are the colors alone, to which boiled seed oil, litharge, Japan varnish, and spirits turpentine are to be added accordi o the application of the paint.

Lamp-black and litharge are ground sepa y with oil, then stirred into the lead and oil.

Thus for black paint: Lamp-black 25 parts, litharge 1, Japan varnish 1, boiled linseed oil 72, and spirits turpentine 1.

Tar Paint.—Coal tar 9 gallons, slaked lime 13 lbs., turpentine or naphtha 2 or 3 quarts.

A GALLON OF PAINT WILL COVER	Superficial feet.	A GALLON OF PAINT WILL COVER	Superficial feet.
On stone or brick, about......	190 to 225	On well-painted surface or iron	600
On composite, etc., from......	300 " 375	One gallon tar, first coat......	90
On wood, from...............	375 " 525	" " " second coat...	160

Boiled Oil.—Raw linseed oil 91 parts, copperas 3, and litharge 6.

Put litharge and copperas in a cloth bag and suspend in middle of a kettle. Boil oil four hours and a half over a slow fire, then let it stand and deposit the sediment.

White Paint.

	Inside work.	Outside work.		Inside work.	Outside work.
White lead, in oil..	80	80	Raw oil..........	—	9
Boiled oil.........	14.5	9	Spirits turpentine.	8	4

New wood-work requires 1 lb. to square yard for three coats.

Coats for 100 *Square Yards New White Pine.*

INSIDE.	White lead.	Raw oil.	Turpentine.	Drier.	OUTSIDE.	White lead.	Raw oil.	Boiled oil.	Turpentine.
	Lbs.	Pts.	Pts.	Lbs.		Lbs.	Pts.	Pts.	Pts.
Priming....	16	—	[illegible]	2[illegible]	Priming....	18.5	2	2	—
2d coat.....	15	3.[illegible]			2d and 3d coats	15	2	2	.5
3d "	13	2							

1 lb. of drier with p

HYDROMETERS.

U. S. Hydrometer (Tralle's) ranges from 0 (water) to 100 (pure spirit); it has not any subdivision or standard termed "Proof," but 50, upon stem of instrument, at a temperature of 60°, is basis upon which computations of duties are made.

In connection with this instrument, a Table of Corrections, for differences in temperature of spirits, becomes necessary; and one is furnished by the Treasury Department, from which all computations of value of a spirit are made.

ILLUSTRATION. — A cask contains 100 gallons of whiskey at 70°, and hydrometer sinks in the spirit to 25 upon its stem.

Then, by table, under 70°, and opposite to 25, is 22.99, showing that there are 22.99 gallons of pure spirit in the 100.

Commercial Hydrometer (Gendar's) has a "Proof" at 60°, which is equal to 50 upon U. S. Instrument and its gradations, run up to 100 with it, and down to 10 below proof, at 0 upon U. S. Instrument; or 0 of the Commercial Instrument is at 50 upon U. S. Instrument, from which it progresses numerically each way, each of its divisions being equal to two of latter.

In testing spirits, Commercial standard of value is fixed at proof; hence any difference, whether higher or lower, is added or subtracted, as case may be, to or from value assigned to proof.

A scale of Corrections for temperature being necessary, one is furnished with a Thermometer.

Application of Thermometer.—Elevation of the mercury indicates correction to be added or subtracted, to or from indication upon stem of hydrometer.

When elevation is above 60°, subtract correction; and when below, add it.

ILLUSTRATION.—A hydrometer in a spirit indicates upon its stem 50 below proof, and thermometer indicates 4 above 60° in appropriate column.

Then $50 - 4 = 46 =$ *strength below proof.*

To Compute Strength of a Spirit, or Volume of its Pure Spirit, by Commercial Hydrometer, and Convert it to Indication of a U. S. Hydrometer.

When Spirit is above Proof. RULE.—Add 100 to indication, and divide sum by 2.

When Spirit is below Proof. RULE. —Subtract indication from 100, and divide remainder by 2.

EXAMPLE. — A spirit is 11 above proof by a Commercial Hydrometer; what proportion of pure spirit does it contain?

$$11 + 100 \div 2 = 55.5 \text{ per cent.}$$

To Compute Strength, etc., by a U. S. Hydrometer.

When Spirit is above Proof. RULE.—Multiply indication by 2, and subtract 100.

When Spirit is below Proof. RULE. —Multiply indication by 2, and subtract it from 100.

EXAMPLE.—A spirit is 55.5; what is its per centage above proof?

$$\overline{55.5 \times 2} - 100 = 11 \text{ per cent.}$$

Commercial practice of reducing indications of a hydrometer is as follows:

Multiply number of gallons of spirit by per centage or number of degrees above or below proof, divide by 100, and quotient will give number of gallons to be added or subtracted, as case may be.

ILLUSTRATION.—50 gallons of whiskey are 11 per cent. above proof.

Then $50 \times 11 \div 100 = 5.5$, which added to $50 = 55.5$ *gallons.*

HYGROMETER.

Dew-point.—When air is gradually lowered in its temperature at a constant pressure, its density increases, and ratio of increase is sensibly same for the vapor as for the air with which it is combined, until a point is reached at which the density of the vapor becomes equal to the maximum density corresponding to the temperature.

This temperature is termed *dew-point* of given mass, and any further reduction of it will induce the condensation of a portion of the vapor in form of dew, rain, snow, or frost, according as temperature of surface is above or below freezing point.

Mason's or like Hygrometer.

To Ascertain Dew-point.

RULE.—Subtract absolute dryness from temperature of air, and remainder is dew-point.

EXAMPLE.—Temperature of air 57°, and absolute dryness 7°.

Hence $57° - 7° = 50°$ *dew-point.*

To Ascertain Absolute Existing Dryness.

RULE.—Subtract temperature of wet bulb from temperature of air, as indicated by a dry bulb, add excess of dryness from following table, multiply sum by 2, and product will give absolute dryness in degrees.

EXAMPLE.—Temperature of air 57°, wet bulb 54°.

Then $57° - 54° = 3°$, and $3° + .5°$ (from table) $\times 2 = 7°$ *absolute dryness.*

Observed Dryness.	Excess of Dryness.	Observed Dryness.	Excess of Dryness.	Observed Dryness.	Excess of Dryness.	Observed Dryness.	Excess of Dryness.	Observed Dryness.	Excess of Dryness.
°	°	°	°	°	°	°	°	°	°
.5	.083	5	.833	9.5	1.583	14	8.333	18.5	3.083
1	.166	5.5	.9165	10	1.666	14.5	2.4165	19	3.166
1.5	.2495	6	1	10.5	1.7495	15	2.5	19.5	3.2495
2	.333	6.5	1.083	11	1.833	15.5	2.583	20	3.333
2.5	.4165	7	1.166	11.5	1.9165	16	2.666	20.5	3.4165
3	.5	7.5	1.2495	12	2	16.5	2.7495	21	3.5
3.5	.583	8	1.333	12.5	2.083	17	2.833	21.5	3.583
4	.666	8.5	1.4165	13	2.166	17.5	2.9165	22	3.666
4.5	.7495	9	1.5	13.5	2.2495	18	3	22.5	3.7495

To Compute Volume of Vapor in Atmosphere.

By a Hygrometer.

When temperature of atmosphere in shade, and of dew-point are given.—If temperature of air and *dew-point* correspond, which is the case when both thermometers are alike, and air consequently saturated with moisture, then in table* opposite to temperature will be found corresponding weight of a cube foot of vapor in grains.

ILLUSTRATION.—Assume temperature of air and dew-point 70°. Then opposite temperature weight of a cube foot of vapor = 8.392 *grains.*

But if temperature of air is different from dew-point, a correction is necessary to obtain exact weight.

ILLUSTRATION.—Assume dew-point 70° as before, but temperature of air in shade 80°, then the vapor has suffered an expansion due to an excess of 10°, which requires a correction.

In table of corrections for 10° is 1.0208. Then divide 8.392 grains at dew-point—viz., 70° by correction corresponding to degrees of absolute dryness—viz., 10°.

$\frac{8.392}{1.0208} = 8.221$ *grains of existing vapor,* which, subtracted from weight of vapor corresponding to temperature of 80°, will give number of grains required for saturation at that temperature.

11.333 grains [illegible] temperature of 80° − 8.221 contained in the air = 3.112 required *for saturation.*

* For table [illegible] Leslie's and [illegible] [illegible]lished by Pike & Sons, New York, and compared with Sir John

ascertain relations of these conditions on natural scale of humidity (complete :ation being 1000), divide weight of vapor at dew-point by weight at tempera- of air, and quotient will give degrees of saturation.

:USTRATION.—Dew-point $= 70°$, weight $= 8.392$.
hen $8.392 \div 11.333$ (at 80°) $= .7405$ degrees of humidity; saturation $= 1000$.

To Compute Weight of Vapor in a Cube Foot of Air.

e Pressures, Temperatures, Volumes, and Density of Steam, p. 708.

ıus, Required weight of vapor in a cube foot of saturated air at 212°.

a temperature of 212° density or weight of 1 cube foot of air $= .038$ *lb.*

density is required for any temperatures not in table, see rule, p. 706.

ımidity.—Condition of air in respect to its moisture involves amount of r present in air and ratio of it to amount which would saturate it at its erature, and it is this element which is denoted by term *humidity*, and :xpressed as a per centage; thus, if weight of vapor present is .7 of that red for saturation, the humidity is 70.

y Air is air, humidity of which is below zero, but it is customary to it dry when its humidity is below the average proportion.

E.—Air in a highly heated space contains as much vapor (when weight of it al) as a like volume of external air, but it is drier as its capacity for vapor ıter.

SUN-DIAL.

To Set a Sun-dial.

:olumn on which dial is to be placed perpendicular to horizon. Ascertain by evel that upper surface is perfectly horizontal; screw on plate loosely by means re screw, and bring gnomon as nearly as practicable to its proper direction.

, bright day set dial at 9 A.M. and 3 P.M. exactly, with a correctly regulated observe difference between them, and correct dial to half difference. Pro- ı same manner till watch and dial are found to agree perfectly. Then fix rmly in that situation, and dial will be correctly set.

is obvious; for, if there were any defects, the Sun's shadow would not agree me indicated by watch, both before and after he passed meridian. Take ›wever, to allow for equation of time, or you may set dial wrong. Best day rear to set a dial is 15th of June, as there is no equation to allow for, and no ın arise from change of declination. A dial may be set without a watch, by ; a circle around centre, and marking spot where top of shadow of an upright piece of wire, placed in centre, just touches circle in A.M., and again in P.M. should be drawn from one spot to the other, and bisected exactly; then a .wn from centre of dial through that bisection will be a true meridian line, :h the XII hours' mark should be set.

CHAINING OVER AN ELEVATION.

$l\,C = L$, and $C = \cos.$ *angle.*

resenting length of line chained, C *cos. angle of elevation with horizon, length of line reduced to horizontal.*

TRATION.—Length of an elevation at an angle of 30° 17′ is 100 feet; what is tal distance?

ble of Cosines, 30° 17′ $= .86354$. Hence, $100 \times .86354 = 86.354$ *feet.*

t out a Right Angle with a Chain, Tape-line, etc.

40 links on chain or feet of line for base, 30 links or feet for perpendicular, or hypothenuse, or in this ratio for any length or d

USEFUL NUMBERS IN SURVEYING.

nverting	Multiplier.	Converse.	For Converting		Converse.
to links..	1.515	.66	Square feet into		4.356
" " ..	4.545	.22	Square yards "		.8

CHRONOLOGY.

Solar day is measured by rotation of the Earth upon its axis with respect to the Sun.

Motion of the Earth, on account of ellipticity of its orbit, and of perturbations produced by the planets, is subject to an acceleration and retardation. To correct this fluctuation, timepieces are adjusted to an average or mean solar day (*mean time*), which is divided into hours, minutes, and seconds.

In *Civil* computations day commences at midnight, or A.M., and is divided into two portions of 12 hours each.

In *Astronomical* computations and in *Nautical* time day commences at M., or 12 hours later than the civil day, and it is counted throughout the 24 hours.

Solar Year, termed also *Equinoctial*, *Tropical*, *Civil*, or *Calendar Year*, is the time in which the Sun returns from one Vernal Equinox to another; and its average time, termed a *Mean Solar Year*, is 365.242 218 solar days, or 365 *days*, 5 *hours*, 48 *minutes*, and 47.6 *seconds*.

Year is divided into 12 *Calendar* months, varying from 28 to 31 days.

Mean Lunar Month, or lunation of the Moon, is 29 days, 12 hours, 44 minutes, 2 seconds, and 5.24 thirds.*

Bissextile or *Leap Year* consists of 366 days; correction of one year in four is termed *Julian*; hence a mean *Julian* year is 365.25 days.

In year 1582 error of Julian computation of a year had amounted to a period of 10 days, which, by order of Pope Gregory VIII., was suppressed in the Calendar, and 5th of October reckoned as 15th.

Error of Julian computation, .007 76 days, is about 1 day in 128.79 years, and adoption of this period as a basis of intercalation is termed *Gregorian Calendar*, or *New Style*,† *Julian Calendar* being termed *Old Style*.

Error of Gregorian year (365.2425 days) amounts to 1 day in 3571.4286 years.

New Style was adopted in England in 1752 by reckoning 3d of September as 14th.

By an English law, the years 1900, 2100, 2200, etc., and any other 100th year, excepting only every 400th year, commencing at 2000, are not to be reckoned bissextile years.

Dominical or *Sunday Letter* is one of the first seven letters of alphabet, and is used for purpose of determining day of week corresponding to any given date. In *Ecclesiastical Calendar* letter A is placed opposite to 1st day of year, January 1st; B to second; and so on through the seven letters; then the letter which falls opposite to first Sunday in year will also fall opposite to every following Sunday in that year. See table, p. 73.

NOTE.—In bissextile years two Dominical letters are used, one before and the other after the intercalary day.

In *Ecclesiastical Year* the intercalary day is reckoned upon 24th of February; hence 24th and 25th days are denoted by same letter, the dominical letter being set back one place.

In *Civil Year* the intercalary day is added at end of February, the change of letter taking place at 1st of March.

Dominical Cycle is a period of 400 years, when the same order of dominical letters and days of the week will return.

Cycle of the Sun, or *Sunday Cycle*, is the 28 years before same order of Dominical letters return to same days of month, and it is considered as having commenced 9 years before the era of Julian Calendar.

To Compute Cycle of the Sun.

RULE.—Add 9 to given year; divide sum by 28; quotient is number of cycles that have elapsed, and remainder is number or years of cycle.

Use of this computation is determination of dominical letter for any given [illegible]ian Calendar for each of the 28 years of a cycle.

† Now adopted in every Christian country except Russia and Greece.

y adoption of *Gregorian Calendar*, order of the letters is necessarily interrupted uppression of the century bissextile years in 1900, 2100, etc., and a table of Doical letters must necessarily be reconstructed for following century.

unar Cycle, or *Golden Number*, is a period of 19 years, after which the new ons fall on same days of the month of Julian year, within 1.5 hours.

ear of birth of Jesus Christ is reckoned first of the Lunar Cycle.

To Compute Lunar Cycle, or Golden Number.

JLE.—Add 1 to given year; divide sum by 19, and remainder is Golden Number.

TE.—If 0 remain, it is 19.

AMPLE.—What is Golden Number for 1879?

$1879 + 1 \div 19 = 98$, and remainder $= 18 =$ *Golden Number.*

act for any year is a number designed to represent age of the moon on 1st day nuary of that year. See table, p. 73.

To Compute the Roman Indiction.

LE.—Add 3 to given year; divide sum by 15, and remainder is Indiction.

TE.—If 0 remain, Indiction is 15.

mber of Direction is the number of days that Easter-day occurs after 21st of h.

ster-day is first Sunday after first full moon which occurs upon or next after of March; and if full moon occurs upon a Sunday, then Easter-day is Sunday and it is ascertained by adding number of direction to 21st of March. It is fore March N + 21, or April N — 10.

USTRATION.—If Number of Direction is 19, then for March, $19 + 21 = 40$, and $31 = 9 = 9$*th of April;*

for April, $19 - 10 = 9 = 9$*th of April.*

E.—Moon upon which Easter immediately depends is termed *Paschal Moon.*

l Moon is 14th day of moon, that is, 13 days after preceding day of new moon.

Days of the Roman Calendar.

nds were the first 6 days of a month, *Nones* following 9 days, and *Ides* remainys.

larch; May, July, and October, *Ides* fell upon 15th and *Nones* began upon 7th. er months *Ides* commenced upon 13th and *Nones* upon 5th.

Roman Indiction and Julian Period see p. 26.

Chronology.

Creation of World (according to Julius Africanus, Sept. 1, 5508; Samaritan Pentateuch, 4700; Septuagint, 5872; Josephus, 4658; Talmudists, 5344; Scaliger, 3950; Petavius, 3984; Hales, 5411).

eluge (according to Hales, 3154).
ricks made and Cement first used.
Tower of Babel finished.
hinese Monarchy.
irst Egyptian Pyramid and Canal.
old and Silver Money first introduced.
etters first used in Egypt.
emnon invents the Egyptian Alphabet.
rockery introduced.
xe, Wedge, Wimble, Lever, Masts and Sails invented by Daedalus of Athens.
oy destroyed.
ariner's Compass discovered in China.
oundation of Rome.
ales asserts *Earth to be spherical.*
ometry, Maps, etc., first introduced.

576. Money coined at Rome.
562. First Comedy performed at Athens.
480. First recorded Map by Aristagoras.
420. First Theatre built at Athens.
336. Calippus calculates the revolution of Eclipses.
320. Aristotle writes first work on Mechanics.
310. Aqueducts and Baths introduced in Rome.
306. First Light-house in Alexandria.
289. First Sun-dial.
267. Ptolemy constructs a Canal from the Nile to the Red Sea.
224. Archimedes demonstrates erties of Mechanical Po the Art of measuring Sur ids, and Sections.
219. Hannibal crossed the Alps
219. Surveying first introduced.
202. Printing introduced in Chi.

B.C.

198. Books with leaves of vellum first introduced by Attalus.
170. Paper invented in China.
168. An eclipse of the Moon which was predicted by Q. S. Gallus.
162. Hipparchus locates the first degree of Longitude and the Latitude at Ferro.
159. Clepsydra, or Water-clock, invented.
146. Carthage destroyed.
70. First Water-mill described.
51. Cæsar invaded Britain.
45. First Julian Year by Cæsar.
8. Augustus corrects the Calendar.

A.D.

69. Destruction of Jerusalem.
79. Destruction of Herculaneum and Pompeii.
214. Grist-mills introduced.
622. Year of Hegira, commencing 16th July; Glazed windows first introduced into England in this cent'y.
667. Glass discovered.
670. Stone buildings introduced into England.
842. Lands first enclosed in England.
933. Printing said to have been invented by the Chinese.
991. Arabic Numerals introduced.
1066. Battle of Hastings.
1111. Mariner's Compass discovered.
1180. Mariner's Compass introduced in Europe.
1368. Chimneys first introduced into Rome from Padua.
1383. Cannon introduced.
1390. Woollens first made.
1434. Printing invented at Mayence.
1460. Wood-engraving invented and First Almanac.
1471. Printing in England by Caxton.
1477. Watches first introduced at Nuremberg.
1492. America discovered.
1497. Vasco de Gama discovers passage to India.
1500. Variation of Mariner's Compass observed.
1522. F. de Magellan circumnavigates the Globe.
1530. Incas conquered by Pizarro.
1545. Needles first introduced.
1586. Potato introduced into Ireland from America.
1590. Telescopes invented by Jansen and used in London in 1608.
1616. Tobacco first introduced into Virginia.
1620. Thermometer invented by Drebel.
1627. Barometer invented.
1629. First Printing-press in America.
1639. First Printing-office in America at Cambridge.
. Otto Van Guericho constructed first [illegible]ctric machine.
[illegible]ds with wooden rails intro[illegible] near Newcastle.
[illegible]spaper Advertisement.
[illegible]spaper in America.
[illegible]st made at Bristol, Eng-

A.D.

1752. Benjamin Franklin demonstrated identity of the electric spark and lightning, by aid of a kite.
1752. New Style, introduced into Britain; Sept. 3 reckoned Sept. 14.
1753. First Steam-engine in America.
1769. James Watt—First design and patent of a Steam-engine with separate vessel of condensation.
1772. Oliver Evans—Designed the Non-condensing Engine. 1792. Applied for a patent for it. 1801. Constructed and operated it.
1774. Spinning-jenny invented by Robert Arkwright.
1776. Iron Railway at Sheffield, England.
1783. First Balloon ascension, and Vessel's bottoms coppered.
1790. Water-lines first introduced in models of Vessels in the U. S.
1797. John Fitch—Propelled a yawl-boat by application of Steam to side-wheels, and also to a screw-propeller, upon Collect Pond, New York.
1807. Robert Fulton — First Passenger Steamboat.
1824. Compound marine steam-engines first introduced by James P. Allan, New York.
1825. Introduction of steam towing by Mowatt, Bros. & Co., of New York, by steam-boat "Henry Eckford," New York to Albany.*
1826. Voltaic Battery discovered by Alex. Volta, and First Horse-railroad.
1827. First Railroad in U. S., from Quincy to Neponset.
1829. First Lucifer Match and first Locomotive in America.
1830. Liverpool and Manchester Railroad opened. First Steel Pen and first Iron Steamer.
1832. S. F. B. Morse invents the Magnetic Telegraph.
1836. Robert L. Stevens first burned Anthracite Coal in furnace of boiler of steamboat "Passaic."
1840. First steam-boiler constructed for burning Anthracite Coal in steamboat "North America," N. Y.
1844. Telegraph line from Washington to Baltimore, Md.
1846. First complete Sewing-machine. Elias Howe, inventor.
1866. Submarine Telegraph laid from Valencia to Newfoundland, N.S.

* Witnessed by author.

›s of Day of Week, corresponding to Day determined by following Table.

›ry, , ›ber.	February,* August.	May.	January, October.	January,* April, July.	September, December.	June.
ɪ	2	3	4	5	6	7
3	9	10	11	12	13	14
5	16	17	18	19	20	21
2	23	24	25	26	27	28
9	30	31				

s, if Monday is the day determined by the year given, the following dates are ›ndays in that year.

›ots, Dominical Letters, and an Almanac, from 1800 to 1901.

OF TABLE.—To ascertain day of the week on which any given day of the ı falls in any year from 1800 to 1901.

›STRATION.—The great fire occurred in New York on 16th of December, 1835; ›as day of the week?

›osite 1835 is Sunday; and by preceding table, under December, it is ascertained ›th was Sunday; *consequently, 16th was Wednesday.*

Days.	Dom. Letters.	Epact.	Years.	Days.	Dom. Letters.	Epact.	Years.	Days.	Dom. Letters.	Epact.
Saturday.	E	4	1834	Saturday.	E	20	1868	Sunday.*	ED	6
Sunday.	D	15	1835	Sunday.	D	1	1869	Monday.	C	·17
Monday.	C	26	1836	Tuesday.*	CB	12	1870	Tuesday.	B	28
Tuesday.	B	7	1837	Wednesd.	A	23	1871	Wednesd.	A	9
Thursday.*	AG	18	1838	Thursday.	G	4	1872	Friday.*	GF	20
Friday.	F	29	1839	Friday.	F	15	1873	Saturday.	E	1
Saturday.	E	11	1840	Sunday.*	ED	26	1874	Sunday.	D	12
Sunday.	D	22	1841	Monday.	C	7	1875	Monday.	C	23
Tuesday.*	CB	3	1842	Tuesday.	B	18	1876	Wednesd.*	BA	4
Wednesd.	A	14	1843	Wednesd.	A	29	1877	Thursday.	G	15
Thursday.	G	25	1844	Friday.*	GF	11	1878	Friday.	F	26
Friday.	F	6	1845	Saturday.	E	22	1879	Saturday.	E	7
Sunday.*	ED	17	1846	Sunday.	D	3	1880	Monday.*	DC	18
Monday.	C	28	1847	Monday.	C	14	1881	Tuesday.	B	29
Tuesday.	B	9	1848	Wednesd.*	BA	25	1882	Wednesd.	A	11
Wednesd.	A	20	1849	Thursday.	G	6	1883	Thursday.	G	22
Friday.*	GF	1	1850	Friday.	F	17	1884	Saturday.*	FE	3
aturday.	E	12	1851	Saturday.	E	28	1885	Sunday.	D	14
unday.	D	23	1852	Monday.*	DC	9	1886	Monday.	C	25
Ionday.	C	4	1853	Tuesday.	B	20	1887	Tuesday.	B	6
Vednesd.*	BA	15	1854	Wednesd.	A	1	1888	Thursday.*	AG	17
hursday.	G	26	1855	Thursday.	G	12	1889	Friday.	F	28
riday.	F	7	1856	Saturday.*	FE	23	1890	Saturday.	E	9
aturday.	E	18	1857	Sunday.	D	4	1891	Sunday.	D	20
onday.*	DC	29	1858	Monday.	C	15	1892	Tuesday.*	CB	1
uesday.	B	11	1859	Tuesday.	B	26	1893	Wednesd.	A	12
'ednesd.	A	22	1860	Thursday.*	AG	7	1894	Thursday.	G	23
ursday.	G	3	1861	Friday.	F	18	1895	Friday.	F	4
turday.*	FE	14	1862	Saturday.	E	29	1896	Sunday		15
inday.	D	25	1863	Sunday.	D	11	1897	Mond		
onday.	C	6	1864	Tuesday.*	CB	22	1898	Tues		
esday.	B	17	1865	Wednesd.	A	3	1899	Wedı		
ursday.*	AG	28	1866	Thursday.	G	14	1900	Thur		
iday.	F	9	1867	Friday.	F	25	1901	Frid		

* *In leap-year, January and February* must be taken in columns marke

To Ascertain Year or Years of Coincidences of a given Day of the Week with a given Day of a Month.

Look in preceding table and ascertain day of week opposite to year of occurrence, and every year in which same day is given will be year of coincidences required.

ILLUSTRATION.—If a child was born on Saturday, 19th Sept. 1829, when could and can his birthdays be celebrated, that occurred or are to occur on same day of week and date of month?

Opposite to 1829 is Sunday, and in preceding table the Sundays for September of that year were 6th, 13th, 20th; hence, if 20th was Sunday, the 19th was Saturday.

Hence, every year in table opposite to which is Sunday are the years of the coincidence required, as 1835, 1840, 1846, 1857, 1863, 1868, 1874, 1885, etc.

MOON'S AGE.

To Compute Moon's Age.

RULE.—To day of month add *Epact* and *Number* of month; from sum subtract 29 days, 12 hours, 44 min. and 2 sec., as often as sum exceeds this period, and result will give Moon's age approximately at 6 o'clock A.M. in United States, east of Mississippi River.

Numbers of the Months.

	d. h.		d. h.		d. h.		d. h.
January	5	April	1 21	July	4 7	October	7 16
February	1 22	May	2 8	August	5 18	November	9 4
March	9	June	3 19	September	7 5	December	9 15

EXAMPLE.—Required age of Moon on 25th February, 1877?

Given day 25 + epact 15 + number of month 1.22 = 41 *d.* 22 *h.* — 29 *d.* 12 *h.* 44 *m.* 2 *sec.* = 12 *d.* 9 *h.* 15 *min.* 58 *sec.*

In Leap-years add 1 day to result after 28th February.

To Compute Age of Moon at Mean Noon at any other Location than that Given.

RULE.—Ascertain age, and add or subtract difference of longitude or time, according as place may be West or East of it, to or from time given.

Or, when time of new Moon is ascertained for a location, and it is required to ascertain it for any other, *add* difference of longitude or time of the place, if East, and *subtract* it if it is West of it.

Moon's Southing, as usually given in United States Almanacs, both Civil and Nautical, is computed for Washington.

To Compute Time of High-water by Aid of American Nautical Almanac.

RULE.—Ascertain time of transit of Moon for Greenwich, preceding time of the high-water required.

For any other location (west of Greenwich), multiply the time in column "diff. for one hour" by longitude of location west of Greenwich, expressed in hours, and add product to time of transit.

NOTE.—It is frequently necessary to take the transit for preceding astronon day, as the latter does not end until noon of day under computation.

EXAMPLE.—Required time of high-water at New York on 25th of August, 1

tude of New York from Greenwich = 4 *h.* 56 *m.* 1.65 *sec.*, which, n *m.*, *the difference* for 1 hour = 10.71 *min.* for correction to be add *to obtain time* of transit at New York.

e of transit, 18 *h.* 38.8 *m.*; then 18 *h.* 38.8 *m.* + 10.71 *m.* = 18 *hours* 49.51 *min.*
e of transit at New York, 24 *d.* 18 *h.* 50 *m.*
ıblishment of the Port, 8 13

25 *d.* 3 *h.* 3 *m.* = *time of high-water.*

E.—Time of 25th at 3 *h.* 3 *m.* Astronomical computation = 25th at 3 *h.* 3 *m.* ıvil Time.

Compute Time of High-water at Full and Change of Moon.

Time of High-water and Age of Moon on any Day being given.

LE.—Note age of Moon, and opposite to it, in last column of following take time, which subtract from time of high-water at this age of , added to 12 *h.* 26 *m.*, or 24 *h.* 52 *m.*, as case may require (when sum to btracted is greatest), and remainder is time required.

MPLE.—What is time of high-water at full and change of Moon at New York?
e of high-water at Governor's Island on 25th of Jan. 1864, was 9 *h.* 20 *m.* A.M. ime. Age of Moon at 12 M. on that day was 16 *d.* 8 *h.* 59 *m.*

osite to 16 *days*, in following table, is 13 *h.* 28 *m.*, and difference between 16 *d.* 5 *d.* 12 *h.* = (16.5 — 16, or 13.53 — 13.28) is 25 *m.*; hence, if 12 *h.* = 25 *m.*, 16 *d.* *m.* — 16 *d.* = 8 *h.* 59 *m.* = 18.71 or 19 *m.*, which, added to 13 *h.* 28 *m.* = 13 *h.*

n 9 *h.* 20 *m.* + 12 *h.* 26 *m.* (as sum to be subtracted is greater than time) — 13 *h.* = 21 *h.* 46 *m.* — 13 *h.* 47 *m.* = 7 *h.* 59 *m.*
is a difference of but 13 minutes from *Establishment* of Port.

ne after apparent Noon before Moon next asses Meridian, Age at Noon being given.

(*S. H. Wright, A.M., Ph.D.*)

Moon at Meridian.	Age of Moon.	Moon at Meridian.	Age of Moon.	Moon at Meridian.	Age of Moon.	Moon at Meridian.	Age of Moon.	Moon at Meridian.
H. M.	Days.	H. M.	Days.	H. M.	Days.	H. M.	Days.	H. M.
P. M.		P. M.		P. M.		A. M.		A. M.
0	6	5 3	12	10 6	18	15 8	24	20 11
25	6.5	5 28	12.5	10 31	18.5	15 34	24.5	20 37
50	7	5 53	13	10 56	19	15 59	25	21 2
1 16	7.5	6 19	13.5	11 21	19.5	16 24	25.5	21 27
1 41	8	6 44	14	11 47	20	16 49	26	21 52
				A. M.				
2 6	8.5	7 9	14.5	12 12	20.5	17 15	26.5	22 17
2 31	9	7 34	15	12 37	21	17 40	27	22 43
2 57	9.5	7 59	15.5	13 2	21.5	18 5	27.5	23 8
3 22	10	8 25	16	13 28	22	18 30	28	23 33
3 47	10.5	8 50	16.5	13 53	22.5	18 56	28.5	23 58
4 12	11	9 15	17	14 28	23	19 21	29	24 24
4 38	11.5	9 40	17.5	14 43	23.5	19 46	29.5	24 48

Tidal Phenomena.

levation of a tidal wave towards the Moon slightly exceeds that of the op- ne, and the intensity of it diminishes from Equator to the Poles.
un by its action twice elevates and depresses the sea every day, following n of the Moon, but with less effect.
g Tides arise from the combined action of the Sun and Moon when they are sides of the Earth.
Tides are the consequence of the divided action of the Sun and Moon, when on opposite sides of the Earth, and the greatest elevations and depressions ccur until the 2d or 3d day after a full or a new Moon.
Sun and Moon are in conjunction, and the time is near to the Equinoxes are fullest. The mean effect of the Moon on the tidal wave he Sun. If, therefore, the Moon caused a tide of 6 feet, the S 33 *feet*; hence a *spring tide* will be 7.33 *feet*, and a neap tide ılar *locations as to contour of* shores, straits, capes, and river *f channels, shoals, etc.*, disturb these general rules.

LATITUDE AND LONGITUDE.

Latitude and Longitude of Principal Locations and Observatories.

Compiled from Records of U. S. Coast and Geodetic Survey and Topographical Engineer Corps, Imperial Gazetteer, and Bowditch's Navigator.

Longitude computed from Meridian of Greenwich.

A., *represents Academy;* Az., *Azimuth;* A. S., *Astronomical Station;* C., *College;* Cap., *Capitol;* Ch., *Church;* C. H., *City Hall;* C. S., *Coast Survey;* Ct., *Court-house;* Cy., *Chimney;* F.S., *Flagstaff;* G.S., *Geodetic Station;* Hos., *Hospital;* L. *Lighthouse;* Obs., *Observatory;* S.H., *State-house;* Sp. *Spire;* Sq., *Square;* S.S., *Signal Station;* T., *Telegraph;* T.H., *Town Hall;* U., *University;* Un., *Union;* B., *Baptist;* Con., *Congregational;* E., *Episcopal;* P., *Presby.;* and M.Ch., *Meth. Churches.*

Location.	Latitude.			Longitude.		
NORTH AND SOUTH AMERICA.		N.			W.	
	°	′	″	°	′	″
Acapulco .... Mex.	16	50	19	99	49	9
Albany, P.Ch.... N.Y.	42	39	3	73	45	24
Ann Arbor......Mich.	42	16	48	83	43	3
Annapolis........ Md.	38	58	42	76	29	6
Apalachicola, F.S. Fla.	29	43	30	84	59	
Astoria, F.S.......Or.	46	11	19	123	49	42
Atlanta, C. H......Ga.	33	44	57	84	23	22
Auburn.........N.Y.	42	55		76	28	
Augusta..........Ga.	33	28		81	54	
Augusta, B.Ch.... Me.	44	18	52	69	46	37
Austin...........Tex.	30	16	21	97	44	12
Balize............La.	29	8	5	89	1	4
Baltimore, Mon't. Md.	39	17	48	76	36	59
Bangor, Tho's Hill. Me.	44	48	23	68	46	59
Barbadoes, S.Pt.. W.I.	13	3		59	37	
Barnegat, L......N. J.	39	46		74	6	
Bath, W.S.Ch.....Me.	43	54	55	69	49	
Baton Rouge......La.	30	26		91	18	
Beaufort, Ct......N.C.	34	43	5	76	39	48
Beaufort, E.Ch... S.C.	32	26	2	80	40	27
Belfast, M.Ch.....Me.	44	25	29	69		19
Benicia, Ch...... Cal.	38	3	5	122	9	23
Benington ....Vt.	42	40		73	18	
Bismarck, S. S ...Neb.	46	48		100	38	
Boston, L........Mass.	42	19	6	70	53	6
Boston, S.H..... "	42	21	30	71	3	30
Brazos Santiago..Tex.	26	6		97	12	
Bridgeport......Conn.	41	10	30	73	11	4
Bristol ....R. I.	41	40	11	71	16	5
Brooklyn, C.H...N.Y.	40	41	31	73	59	27
Brownsville, S.S..Tex.	26			97	30	
Brunswick, A.....Ga.	31	8	51	81	29	26
Brunswick, C.Sp..Me.	43	54	29	69	57	24
Buffalo, L........N.Y.	42	50		78	59	
Burlington ......N. J.	40	4	52	74	52	37
Burlington, C......Vt.	44	28	52	78	10	
Burlington, Pub.Sq., Ia.	40	48	22	91	6	25
Bushnell ....Neb.	41	13	54	103	52	57
Cairo.............Ill.	36	59	48	89	11	14
Calais, C.S. Obs... Me.	45	11	5	67	16	5
		S.				
[illegible] F.S.......Peru	12	4		77	13	
		N.				
[illegible]	42	22	52	71	7	43
[illegible]	34	17		80	33	
[illegible]	19	49		90	33	

Location.	Latitude.			Longitude.		
NORTH AND SOUTH AMERICA.		N.			W.	
	°	′	″	°	′	″
Canandaigua ....N.Y.	42	54	9	77	17	
Cape Ann, S. L...Mass.	42	38	11	70	34	10
Cape Breton ......Va.	45	57		59	48	5
Cape Canaveral...Fla.	28	27	30	80	33	
Cape Cod, L.P.L...Ms.	42	2		70	9	48
Cape Fear ........N.C.	33	48		77	57	
Cape Flattery, L..W.T.	48	23	15	124	43	54
Cape Florida, L...Fla.	25	39	54	80	9	2
Cape Hancock, Colo. R.	46	16	35	124	1	45
Cape Hatteras, L., N.C.	35	15	2	75	30	54
Cape Henlopen, L., Del.	38	46	6	75	4	7
Cape Henry, L....Va.	36	55	30	76	0	2
		S.				
Cape Horn, S. Pt., Hermit's Island........	55	59		67	16	
		N.				
Cape May, L......N.J.	38	55	48	74	57	18
Cape Race........N. S.	46	39	24	53	4	3
Cape Sable........N.S.	43	24		65	36	
Cape Sable, C.S...Fla.	25	6	53	81	15	
		S.				
Cape St. Roque, Brazil	5	28		35	17	
		N.				
Carthagena.......N.G.	10	26		75	38	
Castine............Me.	44	22	30	68	45	
Cedar Keys, Depot Isl.	29	7	30	83	2	45
Chagres...........N.G.	9	20		80	1	21
Charleston, C. Ch., S.C.	32	46	44	79	55	39
Charlestown, Mon., Ms.	42	22	36	71	3	18
Cheboygan, L....Mich.	45	40	9	84	24	37
Chicago, C.Ch.....Ill.	41	53	48	87	37	47
Chickasaw ......Miss.	35	53	30	88	6	25
Cincinnati, Obs.....O.	39	6	26	84	29	45
Cleveland, Hos..... "	41	30	25	81	40	30
Colorado Springs. Col.	38	50		104	49	8
Columbia, S.H....S.C.	33	59	58	81	2	3
Columbus, Cap.....O.	39	57	40	82	59	40
Concord, S.H....N.H.	43	12	29	71	29	
Corpus Christi...Tex.	27	47	18	97	27	2
Council Bluffs..Neb.T.	41	30		95	48	
Crescent City, L...Cal.	41	44	34	124	11	22
Cumberland......Md.	39	39	14	78	45	25
Darien, W.H.......Ga.	31	21	54	81	25	39
Davenport, S. S....Ia.	41	32		90	38	
Dayton..............O.	39	44		84	11	
Deadwood, S.S...Dak.	44	22		103	34	
Decatur, S. S.....Tex.	33	10		97	30	

Latitude and Longitude—*Continued.*

LOCATION.	Latitude.			Longitude.		
...RTH AND SOUTH AMERICA.	N.			W.		
	°	′	″	°	′	″
...ver, S. H. Sp.. Col.	39	45		104	59	33
...Moines, C.H... Ia.	41	35		93	37	16
...oit, St. P. Ch., Mich.	42	19	46	83	2	23
...r .... Del.	39	10		75	30	
...r .... N. H.	43	13		70	54	
...ique........... Ia.	42	29	55	90	39	57
...th, S. S....... Min.	46	48		92	8	
...port, Con. Ch.. Me.	44	54	15	66	59	14
...ton, C. H..... N. C.	36	3	24	76	36	31
...beth City, Ct. "	36	17	58	76	13	23
...L.......... Penn.	42	8	43	80	4	12
...ca, M. Ch.... Cal.	40	48	11	124	9	41
...St. Anth'y.. Minn.	44	58	40	93	10	30
...ndina, A. S.. Fla.	30	40	18	81	27	47
...nce.......... Ala.	34	47	13	87	41	40
...Gibson..... Ind. T.	35	47	35	95	15	10
...Henry...... Tenn.	36	30	22	88	3	40
...Laramie. Wyo. T.	42	12	10	104	47	43
...Leavenworth, Ks.	39	21	14	94	44	
...fort......... Ky.	38	14		84	40	
...rick......... Md.	39	24		77	18	
...ricksburg, E. Ch., Va.	38	18	6	77	27	38
...ricton....... N. B.	46	3		66	38	15
...ston, Cath'l.. Tex.	29	18	17	94	47	26
...etown....... Ber.	32	22	2	64	37	6
...town, E. Ch., S. C.	33	22	8	79	16	49
...ster, U. Ch... Ms.	42	36	46	70	39	59
...Haven, S. S., Mich.	43	5		86	18	
...x, Obs....... N. S.	44	39	4	63	35	
...burg...... Penn.	40	16		76	50	
...rd, S. H... Conn.	41	45	59	72	40	45
..., Moro.... Cuba	23	9		82	21	23
...n the Wall, L., Bahamas	25	51	5	77	10	6
...'s Hole, Ch., Ms.	41	27	13	70	35	59
.... N. Y.	42	14		73	46	
...ille......... Ala.	34	36		86	57	
...polis...... Ind.	39	55		86	5	
...la, G. S..... Tex.	28	32	28	96	31	1
...l.......... Miss.	32	23		90	8	
...ville, M. Ch., Fla.	30	19	43	81	39	14
.... Mex.	19	30	8	96	54	30
...n City..... Mo.	38	36		92	8	
...City, Gas Ch'y.	40	43	28	74	2	24
..., M. Ch... W. T.	46	26		122	50	39
..., S. S........ Ia.	40	23		91	25	
...st, T. Obs., Fla.	24	33	31	81	48	31
...n..... Jamaica	17	58		76	46	
...n, C. H... C. W.	44	8		76	28	37
...le....... Tenn.	35	59		83	54	
...e, Ct. S... Wis.	43	58	50	91	14	48
...r....... Penn.	40	2	36	76	20	33
...A. S....... Tex.	28	37	36	96	37	21
...orth, S. S.. Ks.	39	29		94	58	
...n......... Ky.	38	6		84	18	
		S.				
.... *Peru*	*12*	*3*		*77*	*6*	
		N.				
...ck...... Ark.	*34*	*40*		*92*	*12*	

LOCATION.	Latitude.			Longitude.		
NORTH AND SOUTH AMERICA.	N.			W.		
	°	′	″	°	′	″
Lockport.......... N. Y.	43	11		78	46	
Los Angeles....... Cal.	34	3	5	118	14	32
Louisville......... Ky.	38	3		85	30	
Lowell, St. Ann's Ch., Mass.	42	38	46	71	19	2
Machias, Th........ Me.	44	43	1	67	27	21
Macon, Arsenal.... Ga.	32	50	25	83	37	36
Madison, Dome... Wis.	43	4	33	89	24	3
Marblehead, L... Mass.	42	30	14	70	50	39
Martinique, S. P't. W. I.	14	27		60	55	
Matagorda, G. S... Tex.	28	41	29	95	57	56
Matamoras....... "	25	52	50	97	27	50
Matanzas......... Cuba	23	3		81	40	
Memphis, S. S... Tenn.	35	7		90	7	
Mexico........... Mex.	19	25	45	99	5	6
Milwaukee....... Mich.	43	2	24	87	54	4
Minneapolis, U. C., Min.	44	58	38	93	14	8
Mississippi City, G. S., Miss.	30	22	54	89	1	57
Mobile, E. Ch...... Ala.	30	41	26	88	2	28
Monterey, Az. S... Cal.	36	35	21	121	52	59
		S.				
Montevideo... Rat Is'd	34	53		56	13	
		N.				
Montgomery, S. H., Ala.	32	22	45	86	18	
Montreal......... C. E.	45	31		73	32	56
Mound City........ Ill.	37	4	47	89	12	
Nantucket, L.... Mass.	41	23	24	70	2	24
Nantucket, S. Tower, Mass.	41	16	57	70	5	57
Nashville, U.... Tenn.	36	9	33	86	49	3
Nassau, L........ N. P.	25	5	2	77	21	2
Natchez......... Miss.	31	34		91	24	42
Nebraska, Junction of Forks of Platte Riv.	41	5	5	101	21	24
New Bedford, B. Ch., Mass.	41	38	10	70	55	36
New Haven, Col., Conn.	41	18	28	72	55	45
New London, P. Ch. "	41	21	16	72	5	29
New Orleans, Mint, La.	29	57	46	90	3	28
NEW YORK, C. H., N. Y.	40	42	44	74		24
Newbern, E. Sp... N. C.	35	6	21	77	5	
Newburg, A. Sp., N. Y.	41	30	6	74		33
Newburyport, L., Mass.	42	48	30	70	52	28
New Castle, E. Ch., Del.	39	39	36	75	33	48
Newport, Sp...... R. I.	41	29	12	71	18	49
Norfolk, C. H...... Va.	36	50	47	76	7	22
Norwalk....... Conn.	41	2	50	73	25	35
Norwich........ "	41	33		72	7	
Ocracoke, L...... N. C.	35	6	28	75	58	51
Ogdensburg, L... N. Y.	44	45		75	30	
Old Point Comfort, Va.	37		2	76	18	6
Olympia...... Wash. T.	47	3		122	55	
Omaha, P. Ch.... Neb.	41	15	43	95	56	14
Oswego, S. S...... N. Y.	43	28	32	76	35	5
Ottawa.......... Can.	45	23		75	42	
Panama, Cath'l... N. G.	8	57	9	79	27	17
Parkersburg.... W. Va.	[illegible]	[illegible]	[illegible]	81	34	12
Pascagoula...... Miss.				[illegible]	[illegible]	45
Pensacola, Sq're.. Fla						
Petersburg, C. H... Va						

Latitude and Longitude—*Continued.*

LOCATION.	Latitude.	Longitude.
NORTH AND SOUTH AMERICA.	N.	W.
	° ′ ″	° ′ ″
Philadelphia, S. H., Pa.	39 56 53	75 9 3
Pike's Peak, S.S.. Col.	38 48	104 59
Pittsburg.......Penn.	40 32	80 2
Plattsburg, Sp....N.Y.	44 41 57	73 26 54
Plymouth, Pier ...Ms.	41 58 44	70 39 12
Point Hudson....W.T.	48 7 3	122 44 33
Port au Prince...W. I.	18 33	72 16 3
Port Townshend, A.S., Wash. T.	48 6 56	122 44 58
Portland, C. H.....Me.	43 39 28	70 15 1
Portland, S. S.......O.	45 30	122 27 30
Porto Bello......N. G.	9 34	79 40
Porto Cabello, Maracaibo	10 28	68 7
Portsmouth, L...N. H.	43 4 16	70 42 34
Prairie du Chien.. Wis.	43 2	91 8 35
Princeton, S.Cap., N.J.	40 20 40	74 39 55
Providence, U.Ch., R.I.	41 49 26	71 24 19
Provincetown, Sp., Mass.	42 3	70 11 18
Puebla de los Angelos, Mex.	19 15	98 2 21
Quebec, Citadel. Can'a	46 49 12	71 12 15
Queenstown .... "	43 9	79 8
Raleigh, Square.. N.C.	35 46 50	78 38 5
Richmond, Cap.... Va.	37 32 16	77 26 4
	S.	
Rio de Janeiro, S. Loaf.	22 56	43 9
	N.	
Rochester, R. H.. N.Y.	43 8 17	77 51
Rockland, E.Ch...Me.	44 6 6	69 6 52
Sackett's Harbor, N.Y.	43 55	75 57
Sacramento.......Cal.	38 34 41	121 27 44
Salem, So.......Mass.	42 31 10	70 53 58
Salt Lake City, Obs., Utah	40 46 4	111 53 47
Saltillo..........Mex.	25 26 22	101 4 45
San Antonio.....Tex.	29 25 22	98 29 15
San Buenaventura, G. S............Cal.	34 15 46	119 15 56
San Diego, A.S.... "	32 43 68	117 9 40
San Francisco, C. S. Station.........Cal.	37 48	122 23 19
San José, Sp...... "	37 19 58	121 53 39
San Luis Obispo.. "	35 10 38	120 43 31
San Pedro........ "	33 43 20	118 16 3
Sandusky, L........O.	41 32 30	82 42 15
Sandy Hook, L...N.J.	40 27 40	74 9
Santa Barbara, M. Ch., Cal.	34 26 10	119 42 42
[illegible]ta Clara, C. Ch.. "	37 20 49	121 26 56
[illegible]ta Cruz, F. S.. "	36 57 31	122 1 29
[illegible] Fé......N. Mex.	35 41 6	106 1 22
[illegible]h, Sp......Ga.	32 4 52	81 5 26
[illegible]ty......N. Y.	42 48	73 55
[illegible] R. D., Wy.	41 7 50	105 23 33
[illegible] ..La.	32 30	93 45
[illegible] N. C.	33 54 58	78 1 8
[illegible]ss. [illegible] Ill.	39 47 57	89 39 20
[illegible]	[illegible]	72 36
[illegible]		[illegible]1 35

LOCATION.	Latitude.	Longitude.
NORTH AND SOUTH AMERICA.	N.	W.
	° ′ ″	° ′ ″
St. Augustine, P. Ch., Fla.	29 53 20	81 18 41
St. Bartholomew. S. Point.........W. I.	17 53 30	62 56 54
St. Christopher, N. Pt., W. I.	17 24	62 50
St. Croix, Obs.... "	17 44 30	64 40 42
St. Domingo..... "	18 29	69 52
St. Eustatia, Town. "	17 29	63
St. Jago de Cuba, Entrance........W. I.	19 58	75 52
St. John.........N. B.	45 14 6	66 3 30
St. Joseph..... L. Cal.	23 3 13	109 40 44
St. Louis, W. U..... "	38 8 3	90 12 4
St. Mark's, Fort.. Fla.	30 9 1	84 12 30
St. Martin's, Fort, W. I.	18 5	63 3
St. Mary's, M. H...Ga.	30 43 12	81 32 53
St. Paul........Minn.	44 52 46	95 4 54
St. Thomas, Fort Ch'n, W. I.	18 21	64 55 18
St. Vincent's, S. Point, W. I.	13 9	61 14
Staunton..........Va.	38 8 51	79 4 15
Stockton, S.S.....Tex.	30 50	102 50
Stonington, L....Conn.	41 19 36	71 54
Sweetwater River, Mouth of...Wyo. T.	42 27 18	107 45 27
Sydney, S. S......N. S.	46 12	60 12
Syracuse........N. Y.	43 3	76 9 16
Tallahassee.......Fla.	30 28	84 36
Tampa Bay, E. Key "	27 36	82 45 15
Tampico, Bar....Mex.	22 15 30	97 51 51
Taunton, T.C.Ch., Mass.	41 54 11	71 5 55
Tobago, N. E. P'r, W. I.	11 20	60 27
Toronto..........Can.	43 39 35	79 23 21
Trenton, P. Ch ...N. J.	40 13 10	74 45 50
Trinidad, Fort...W. I.	10 39	61 32
Troy, D. Ch........N.Y.	42 43	73 2 16
Tuscaloosa........Ala.	33 12	87 42
Utica, Dut. Ch....N.Y.	43 6 49	75 13
	S.	
Valparaiso, Fort.. Chili	33 2	71 41
	N.	
Vandalia..........Ill.	38 50	89 2
Vera Cruz.......Mex.	19 11 52	96 8 36
Vicksburg, S. S...Miss.	32 23	90 54
Victoria..........Tex.	28 46 57	97 1
Vincennes........Ind.	38 43	87 25
Virginia City, S.S., M.T.	45 20	112 3
WASHINGTON...Capitol	38 53 20	77 36
Watertown, Ars'l.. Ms.	42 21 41	71 9 45
West Point......N. Y	41 23 26	73 57 1
Wheeling.........Va.	40 7	80 42
Wilmington, E. Ch., N. C.	34 14 2	77 56 38
Wilmington, T.H.. Del.	39 44 27	75 33 3
Worcester, Ant. H.. Ms.	42 16 17	71 48 13
Yankton, S.S.....Dak.	42 45	97 30
Yazoo..........Miss.	33 5	90 20
York...........Penn.	39 58	76 40
Yorktown........Va.	37 13	76 34

Latitude and Longitude—*Continued.*

...N.	Latitude.	Longitude.
AFRICA, EANS.	N.	E.
	° ′ ″	° ′ ″
....	36 11	37 10
....	31 12	29 53
....	36 47	3 4
....	52 22	4 53
....	51 13	4 24
....	64 32	40 33
....	37 58	23 44
....	41 23	2 11
	S.	
....	6 8	106 50
rt, Su'a.	3 48	102 19
	N.	
....	52 30 16	13 23 45
....	18 56	72 54
	S.	
Roads.	34 2	151 13
	N.	
....	53 5	8 49
		W.
....	51 27	2 35
		E.
....	50 51 11	4 22
....	30 30	48
		W.
....	36 32	6 18
		E.
....	30 3	31 18
....	50 58	1 51
....	22 34	68 20
....	35 31	25 8
....	23 7	113 14
		W.
....	51 26	9 29
	S.	E.
e, Obs..	33 56 3	18 28 45
Mad'r..	25 39	45 7
	N.	
edro ...	9 49	80 23
....	59 55	10 43
	S.	
....	6 8	12 9
	N.	
, St. S..	41 1	28 59
....	55 41	12 34
....	37 54	22 52
....	59 59	29 47
....	51 8	1 19
		W.
....	53 23 12	6 20 30
....	55 57	3 12
ads, St	S.	
....	15 55	5 45
	N.	
nt	38 30	28 42
Ovolau,	S.	E.
....	17 41	178 53
	N.	
....	43 46	11 16
		W.
ira....	32 38	16 55
		E.
....	46 11 59	6 9 15

Location.	Latitude.	Longitude.
EUROPE, ASIA, AFRICA, AND THE OCEANS.	N.	E.
	° ′ ″	° ′ ″
Genoa................	44 24	8 53
		W.
Gibraltar.............	36 7	5 22
Glasgow	55 52	4 16
GREENWICH	51 28 38	—
		E.
Hamburg.............	53 33	9 58
Havre	49 29	6
	S.	W.
Hawaii or Owyhee....	20 23	155 54
	N.	E.
Hongkong	22 16 30	114 14 45
Honolulu	21 18 12	157 30 36
		W.
Hood Isl'd, Gallapagos	1 23	89 46
	S.	E.
Hood's Island, Marquesas.............	9 26	138 57
	N.	
Jeddo or Tokio........	35 40	139 40
Jerusalem	31 48	37 20
Leghorn, L...........	43 32	10 18
Leipsic	51 20 20	12 22
Leyden...............	52 9 28	4 29 15
		W.
Lisbon...............	38 42	9 9
Liverpool, Obs........	53 24 48	3
		E.
Madras..............	14 4 9	80 15 45
		W.
Madrid	40 25	3 42
		E.
Majorca, Castle.......	39 34	2 23
		W.
Malaga	36 43	4 26
		E.
Malta, Valetta........	35 54	14 30
Manila...............	14 36	121 2
Marseilles............	43 18	5 22
Messina, L.	38 12	15 35
Mocha	13 20	43 12
Moscow..............	55 40	35 33
Muscat	23 37	58 35
Naples, L.............	40 50	14 16
		W.
New Castle...........	54 58	1 37
	S.	E.
New Hebrides, Table Island	15 28	167 7
	N.	
Niphon, Cape Idron, Japan	34 36 3	138 50 35
Odessa..............	46 28	30 44
Palermo, L.	38 8	13 22
Paris, Obs............	48 50 13	2 20
Pekin................	39 54	116 28
		W.
Plymouth............	50 21	4 9
Port Jackson..N.S.W.		
Porto Praya, Cape Verd Islands		
Prince of Wales Island.		

Latitude and Longitude—*Continued.*

LOCATION.	Latitude.	Longitude.
EUROPE, ASIA, AFRICA, AND THE OCEANS.	N.	W.
	° ′ ″	° ′ ″
Queenstown	51 47	8 19
		E.
Rome, St. Peter's	41 54	12 27
Rotterdam	5 54	4 29
		W.
Santa Cruz.....Ten'fe	28 28	16 16
Scilly, St. Agnes, L.	49 54	6 21
Senegal, Fort	16 1	16 32
		E.
Sevastopol	44 37	33 30
Seville	36 59	5 58
Siam	14 55	100
	S.	W.
Sierra Leone	8 30	13 18
	N.	E.
Singapore	1 17	103 50
Smyrna	38 26	27 7
		W.
Southampton	51	1 30
	S.	
St. Helena	15 55	5 45

LOCATION.	Latitude.	Longitude.
EUROPE, ASIA, AFRICA, AND THE OCEANS.	N.	E.
	° ′ ″	° ′ ″
St. Petersburg	59 56	30 19
Suez	29 59	32 34
Surat, Castle	21 11	72 47
	S.	
Sydney........N.S.W.	33 33 42	151 23
		W.
Tahiti or Otaheite	17 45	149 30
	N.	E.
Tangier	35 47	5 54
Toulon	43 7	5 22
Tripoli	34 54	13 11
Tunis, City	36 47	10 6
Venice	40 50	14 26
Vienna	48 13	16 23
Warsaw, Obs.	52 13 5	21 2 9
	S.	
Wellington...New Z'd	41 14	174 44
	N.	
Yokohama	35 26	139 39
	S.	
Zanzibar Island, Sp...	6 28	39 33

Observatories.—*Not included in previous Table.*

Longitude given in Time.

LOCATION.	Latitude.	Longitude.
	N.	W.
	° ′ ″ ‴	h. m. s.
Albany, Dudley	42 39 49.55	4 54 59.52
Allegheny, Penn.	40 27 36	5 20 2.9
Birr Castle, Earl of Rosse	53 5 47	31 40.9
Cambridge, U. S.	42 22 52	4 44 30.9
		E.
Cambridge, Eng.	52 12 51.6	22.75
	S.	
Cape of G. Hope	33 56 3	1 13 55
	N.	
Copenhagen, Un'y.	55 40 53	50 19.8
		W.
Crescent City, A. S., Cal.	41 44 43	8 16 49.1
Dublin	53 23 13	25 22
Edinburgh	55 57 23.2	12 43.6
		E.
Florence	43 46 41.4	45 3.6
Geneva	46 11 59.4	24 37.7
		W.
Georgetown, U. S.	38 53 39	5 8 12.5
Gibbes's, Charleston, U. S.	32 47 7	5 19 44.7
[illegible]ICH	51 28 38	—
		E.
[illegible]	53 33 5	39 54.1
[illegible]	51 20 20.1	49 28.5
[illegible]	9 28.2	17 57.5
		W.
[illegible]	47.8	12 0.11
		57

LOCATION.	Latitude.	Longitude.
	N.	E.
	° ′ ″ ‴	h. m. s.
Madras	13 4 8.1	5 20 57.3
Marseilles	43 17 50	21 29
		W.
Mitchell's, Cin., O.	39 6 26	5 37 59
		E.
Moscow	55 45 19.8	2 30 16.96
Munich, Bogenh'n	48 8 45	46 26.5
Palermo	38 6 44	53 24.17
		W.
Portsmouth	50 48 3	4 23.9
Quebec	46 48 30	4 44 49.02
		E.
Rome, College	41 53 52.2	49 54.7
		W.
Salt Lake City, Utah	40 46 4	7 27 35.1
San Francisco, Sq., Cal.	37 47 55	8 9 38.1
	S.	
Santiago de Chili	33 26 24.8	4 42 18.9
	N.	
St. Croix, W. I.	17 44 30	4 18 42.8
		E.
St. Petersburg, A.	59 56 29.7	2 1 13.5
Stockholm	59 20 31	1 12 24.8
	S.	
Sydney	33 51 41.1	10 4 59.86
	N.	W.
Tifft's, Key West, Fla.	24 33 31	5 27 14.1
		E.
Unkrechtsberg, Olmutz	49 35 40	1 9 0.1
		W.
Washington	38 53 39	5 8 12.03
West Point, N.Y.	41 23 26	4 55 48

DIFFERENCE IN TIME.

rence in Time at following Locations.

ngitude computed both from New York and Greenwich.

ifference of Time between New York and Greenwich is 4 *h.* 56 *m.* ; in following table 2 seconds are given when the decimal in any xceeds .5 seconds.

F representing Fast, and S Slow.

t.	New York.	Greenwich.	Location.	New York.	Greenwich.
	h. m. s.	*h. m. s.*		*h. m. s.*	*h. m. s.*
......	1 43 15 S.	6 39 17 S.	Cedar Keys........	36 9 S.	5 32 11 S.
......	1 F.	4 55 2	Chagres............	24 3	5 20 5
Egypt	6 55 34	1 59 32 F.	Charleston.........	23 41	5 19 43
......	5 8 18	12 16	Charlestown	11 48 F.	4 44 13
......	5 16 5	19 32	Cheboygan.........	41 37 S.	5 37 38
......	5 13 38	17 36	Chicago............	54 30	5 50 31
......	43 54 S.	5 39 56 S.	Chickasaw.........	56 24	5 52 26
......	3 19 17	8 15 19	Cincinnati.........	41 57	5 37 59
......	41 32	5 37 33	Cleveland..........	30 40	5 26 42
......	9 50	5 5 52	Colorado Springs..	2 3 15	6 59 17
...Ga.	31 34	5 27 36	Columbia..........	28 7	5 24 8
...Mo.	16 55 F.	4 39 6	Columbus..........	35 57	5 31 59
......	1 34 55 S.	6 30 27	Concord...........	10 6 F.	4 45 56
......	10 26	5 6 28	Constantinople....	6 51 58	1 55 56 F.
......	20 54 F.	4 35 8	Copenhagen.......	5 46 18	50 16
.Pt....	57 34	3 58 28	Corpus Christi.....	1 33 47 S.	6 29 48 S.
......	22 S.	4 56 24	Council Bluffs.....	1 27 10	6 23 12
......	16 46 F.	4 39 16	Crescent City	3 20 44	8 16 45
......	1 9 10 S.	6 5 12	Darien.............	29 41	5 25 43
..N.C.	10 38	5 6 39	Davenport.........	1 12 30	6 2 32
..S.C.	26 39	5 22 40	Dayton............	40 42	5 36 44
......	20 1 F.	4 36 1	Deadwood	1 58 30	6 54 32
......	3 12 36 S.	8 8 38	Denver............	2 3 57	6 59 58
......	5 49 37 F.	53 35 F.	Detroit............	36 76	5 32 10
......	1 46 30 S.	6 42 32 S.	Dover ....Del.	35 58	5 2
......	9 47 38 F.	4 51 36 F.	Dover.........N.H.	12 26 F.	4 43 36
......	11 47 .6	4 44 14 S.	Dublin............	4 30 40	25 22
......	5 31 18	35 16 F.	Dubuque..........	1 6 38 S.	6 2 40
......	3 17	4 52 44 S.	Duluth............	1 12 10	6 8 32
Yard.	4	4 55 58	Eastport..........	28 6 F.	4 27 56
...Me.	16 12	4 39 50	Edenton..........	10 24 S.	5 6 26
...Ga.	29 56 S.	5 25 58	Edinburgh........	4 43 14 F.	12 48
......	5 13 30 F.	17 28 F	Elizabeth City, N.C.	8 52 S.	5 4 54
s.....	1 2 34	3 53 28 S.	Erie..............	24 15	5 20 17
......	19 54 S.	5 15 56	Eureka...........	3 20 37	8 16 39
...Ia.	1 8 24	6 4 26	Falls St. Anthony..	1 16 40	6 12 42
..N. J.	3 29	4 59 30	Fernandina.......	29 50	5 25 51
...Vt.	16 38	5 12 40	Fire Island, L.....	3 10 F.	4 52 51
..Neb.	1 59 30	6 55 32	Florence......Ala.	54 45 S.	5 50 47
......	4 30 50 F.	25 12	Fort Gibson.......	1 24 59	6 21 1
......	7 1 14	2 5 12 F.	Fort Henry..Tenn.	56 13	5 52 15
...Ill.	1 43 S.	5 56 45 S.	Fort Laramie......	2 3 9	6 59 11
..Me.	26 57 F.	4 29 4	Fort Leavenworth.	1 22 54	6 18 56
......	10 49 22	5 53 20 F	Frederick.........	13 10	5 9 12
......	12 50 S.	5 8 52 S.	Fredericksb'g..Va.	13 49	5 9 51
.Mass.	11 30 F.	4 44 31	Fredericton...N.B.	29 29 F.	4 20 33
......	12 28 58	7 32 56 F.	Funchal..........	3 48 22	1 7 40
ul....	1 2 10 S.	5 58 12 S.	Galveston........	1 23 8 S.	6 19 10
Hope.	6 9 57 F.	1 13 55 F.	Geneva...........	5 20 20 F.	24 37 F.
......	26 58	4 29 4 S.	Geneva.......N.Y.	[illegible]	
......	2 56 S.	4 58 58	Genoa............	5	
......	1 23 46 F.	3 32 16	Georgetown...Ber.		
......	6 30 S.	5 2 32	Georgetown...S.C.		
......	21 2 F.	4 35	Gibraltar..........	[illegible]	

Difference in Time—*Continued.*

Location.	New York. h. m. s.	Greenwich. h. m. s.
Glasgow	4 38 58 F.	17 4 S.
Gloucester	13 22	4 42 40
Grafton	24 5 S.	5 20 7
Grand Haven	49 10	5 45 12
GREENWICH	4 56 1.6	—
Halifax	41 42 F.	4 14 40
Hamburg	5 35 54	39 52 F.
Harrisburg	11 18 S.	5 7 20 S.
Hartford	5 19 F.	4 50 43
Havana, Morro	33 24 S.	5 29 26
Havre	4 56 26 F.	24 F.
Hawaii or Owyhee	5 27 34 S.	10 23 36 S.
Hongkong	12 27 1 F.	7 36 59 F.
Honolulu	15 27 30	10 31 28
Hudson	1 12	4 54 40 S.
Huntsville	51 46 S.	5 47 48
Indianapolis	48 18	5 44 20
Indianola	1 30 2	6 26 4
Jackson	1 4 30	6 0 32
Jacksonville	30 35	5 26 37
Jalapa	1 31 36	6 27 38
Jeddo or Tokio	14 16 2 F.	9 20 F.
Jefferson City	1 12 30 S.	6 8 32 S.
Jersey City	8	4 56 10
Jerusalem	7 25 22 F.	2 29 20 F.
Kalama	3 15 21 S.	8 11 23 S.
Keokuk	1 9 38	6 5 40
Key West	31 13	5 27 14
Kingston....Can.	9 53	5 5 54
Kingston....Jam.	11 2	5 7 4
Knoxville	39 34	5 35 36
La Crosse	1 8 58	6 4 59
La Guayra	27 54 F.	4 28 8
Lancaster	19 21 S.	5 15 22
Lavaca	1 30 27	6 26 29
Leavenworth	1 23 40	6 19 52
Leghorn	5 37 14 F.	41 12 F.
Lexington	41 10 S.	5 37 12 S.
Lima	12 22	5 8 24
Lisbon	4 19 26 F.	36 36 F.
Little Rock	1 12 46 S.	6 8 48 S.
Liverpool	4 44 2 F.	12
Lockport	19 2 S.	5 15 4
Los Angeles	2 56 16	7 52 18
Louisville	45 58	5 42
Lowell	10 45 F.	4 45 16
Machias Bay	26 12	4 29 49
Macon	38 28 S.	5 34 30
Madison	1 1 35	5 57 36
Madrid	4 41 14 F.	14 48
Malaga	4 38 18	17 44
Malta	5 54 2	58 F.
Manila	13 10	8 4 8
Maracaibo	9 2	4 47 S.
Marblehead, L.	12 41	4 43 21
Marseilles	5 17 20	21 28 F.
[Martinique]	52 22	4 3 40 S.
[illegible]	[illegible]7 50 S.	6 23 52
[illegible]	3 50	6 29 51
[illegible]	[illegible] 38	5 26 40
[illegible]	[illegible]	6 0 28
[illegible]		6 36 20

Location.	New York. h. m. s.	Greenwich. h. m. s.
Milwaukee	55 35 S.	5 51 36 S.
Minneapolis	1 16 55	6 12 57
Mississippi City	1 6	5 56 8
Mobile	56 7	5 52 9
Montauk Point	18 22 F.	4 37 40
Monterey	3 11 30 S.	8 7 32
Montevideo	1 11 10 F.	3 44 52
Montgomery	49 10 S.	5 45 12
Montreal	1 50 F.	4 54 12
Montserrat	47 14	4 8 48
Moscow	7 18 14	2 22 12 F.
Mound City	1 26 S.	5 56 28 S.
Nantucket	15 38 F.	4 40 24
Naples	5 53 6	57 4 F.
Nashville	51 15 S.	5 47 16 S.
Nassau	13 23	5 9 24
Natchez	1 9 37	6 5 39
Nebraska	1 49 24	6 45 26
New Bedford	12 19 F.	4 43 42
New Haven	4 19	4 51 43
New London	7 40	4 48 22
New Orleans	1 4 12 S.	6 14
NEW YORK	—	4 56 1.6
Newbern	12 18	5 8 20
Newburg	1	4 56 2
Newburyport	12 32 F.	4 43 30
New Castle	4 49 34	6 28
New Castle...Del.	6 13 S.	5 2 15
Newport	10 46 F.	4 45 15
Norfolk	9 8 S.	5 5 9
Norwalk	2 19 F.	4 53 42
Norwich	7 34	4 48 28
Ocracoke	7 54 S.	5 3 55
Odessa	6 58 58 F.	2 2 56 F.
Ogdensburg	5 58 S.	5 2 S.
Old Point Comfort	9 11	5 5 12
Olympia	3 15 38	8 11 40
Omaha	1 27 43	6 23 45
Oswego	10 19	5 6 20
Ottawa	6 46	5 2 48
Paducah	58 22	5 54 24
Palermo	5 49 30 F.	53 28 F.
Panama	1 21 48 S.	5 17 49 S.
Paris	5 5 22 F.	9 20 F.
Parkersburg	30 15 S.	5 26 37 S.
Pekin	12 41 54 F.	7 45 52 F.
Pensacola	52 50 S.	5 48 52 S.
Petersburg	13 35.	5 9 37
Philadelphia	4 34 6	5 36.2
Pike's Peak	2 3 50	6 59 52
Pittsburg	24 6	5 20 8
Plattsburg	2 14 F.	4 53 48
Plymouth	4 39 26	16 36
Plymouth...Mass.	13 25	4 42 37
Port Au Prince, St. Domingo	16 34	4 39 28
Port Townshend	3 14 58 S.	8 11
Portland	15 2 F.	4 41
Portland......Or.	3 13 48 S.	8 9 50
Porto Praya	3 23 50 F.	1 32 18
Porto Rico	33 26	4 22 36
Portsmouth	13 11	4 42 51

Difference in Time—*Continued.*

Location.	New York.	Greenwich.
	h. m. s.	h. m. s.
Prairie du Chien	1 8 33 S.	6 4 34 S.
Princeton	2 38	4 58 40
Providence	10 24 F.	4 45 37
Provincetown	15 16	4 40 45
Quebec	11 13	4 44 49
Queenstown, L.	4 42 46	33 16
Raleigh	18 31 S.	5 14 32
Richmond	13 43	5 9 44
Rio de Janeiro	2 3 26 F.	2 52 36
Rochester	15 22 S.	5 11 24
Rockland	19 34 F.	4 36 27
Rome	5 45 50	49 48 F.
Rotterdam	5 13 58	17 56
Sackett's Harbor	7 46 S.	5 3 48 S.
Sacramento	3 9 49	8 5 51
Salem	12 26 F.	4 43 36
Salt Lake City	2 31 34 S.	7 27 35
Saltillo	1 48 17	6 44 19
San Antonio	1 37 55	6 33 57
San Buenaventura	3 1 2	7 57 4
San Diego	2 52 37	7 47 39
San Francisco, C. S. S.	3 13 32	8 9 33
San Francisco, P.	3 13 50	8 9 51
San José	3 11 33	8 7 35
Sandusky	34 47	5 30 49
Sandy Hook	1 F.	4 56 1
Santa Barbara	3 2 49 S.	7 58 50
Santa Clara	3 9 46	8 5 48
Santa Cruz	3 12 4	8 8 6
Santa Cruz. Ten'fe	3 50 58 F.	1 5 4
Santa Fé	2 8 4 S.	7 4 5
Savannah	28 20	5 24 22
Schenectady	22 F.	4 55 40
Seville	4 32 10	23 52
Sherman	2 5 33 S.	7 1 34
Shreveport	1 18 58	6 15
Siam	11 36 2 F.	6 40 F.
Sierra Leone	4 2 50 S.	53 12 S.
Singapore	11 51 22 F.	6 55 20 F.
Smithville	16 3 S.	5 12 5 S.
Smyrna	6 44 30 F.	1 48 28 F.
Southampton	4 50 2	6 S.
Springfield....Ill.	1 2 36 S.	5 58 37
Springfield..Mass.	5 39 F.	4 50 24
St. Augustine	29 13 S.	5 25 15
St. Croix, Obs.	37 19 F.	4 18 43
St. Helena	4 33 2	23
St. Jago de Cuba	7 26 S.	5 3 28
St. John	31 48 F.	4 24 14
St. Joseph..L. Cal.	2 22 41 S.	7 18 43

Location.	New York.	Greenwich.
	h. m. s.	h. m. s.
St. Louis	4 47 S.	6 48 S.
St. Mark's	40 48	5 36 50
St. Mary's	30 10	5 26 12
St. Paul	11 24 18	6 20 20
St. Petersburg	6 57 18 F.	2 1 16 F.
St. Thomas, Fort	36 20	4 19 41 S.
Staunton	20 15 S.	5 16 17
Stockholm	6 8 26 F.	1 12 25 F.
Stonington	8 26	4 37 36 S.
Suez	7 6 18	2 10 16 F.
Sweetwater River, Mouth of	2 15 S.	7 11 2 S.
Sydney......N. S.	8 2 F.	4 48
Sydney...N. S. W.	15 1 34	10 5 32 F.
Syracuse	8 35 S.	5 4 37 S.
Tahiti or Otaheite	14 44 2 F.	9 48 F.
Tallahassee	42 22 S.	5 38 24 S.
Tampa Bay	34 59	5 31 1
Tampico Bar	1 35 25	6 31 27
Taunton	11 38 F.	4 44 24
Toronto	21 32 S.	5 17 33
Toulon	5 17 30 F.	21 28 F.
Trenton	3 2 S.	4 59 3 S.
Tripoli	5 48 36 F.	52 44 F.
Troy	3 54	4 52 9 S.
Tunis	5 36 26	40 24 F.
Turk's Island	11 22	4 44 40 S.
Tuscaloosa	54 46 S.	5 50 48
Utica	4 50	5 52
Valparaiso	9 18	4 46 44
Vandalia	1 6	5 56 8
Venice	5 53 46 F.	57 44 F.
Vera Cruz	1 28 33 S.	6 24 34 S.
Vicksburg	1 7 34	6 3 36
Victoria.....Tex.	1 32 2	6 28 4
Vienna	6 1 34 F.	1 5 32 F.
Vincennes	53 38 S.	5 49 40 S.
Virginia City	2 32 10	7 28 12
Warsaw	6 20 11 F.	1 24 9 F.
Washington, Obs.	12 10 S.	5 8 12 S.
West Point	14 F.	4 55 48
Wheeling	26 46 S.	5 22 48
Wilmington..Del.	6 11	5 2 12
Wilmington..N. C.	15 45	5 11 47
Worcester	8 49 F.	4 47 13
Yankton	1 33 58 S.	6 30
Yazoo	1 5 18	6 1 20
Yeddo	14 14 42 F.	9 18 40 F.
Yokohama	14 14 43	9 18 41
York	10 38 S.	5 6 40 S.
Yorktown	10 14	5 6 16

To Compute Difference of Time between New York and Greenwich and any Location not given in Table.

Rule. — Reduce longitude of location to time, and if it is W. of assumed meridian it is *Slow;* if E., it is *Fast.*

If difference for New York is required, and it exceeds 4 h. 56 m. 2 sec., subtract this *time, and remainder* will give difference of time, S.; and *if it (4 h. 56 m. 2 sec.) does not* exceed it, subtract difference from it *nd remainder will give difference* of time, F.

TIDES.

Tide-Table for Coast of United States,

*Showing Time of High-water at Full and New Moon, termed **Establishment** of the Port, being Mean Interval between Time of Moon's **Transit** and Time of High-water.* (*U. S. Coast and Geodetic Survey.*)

Locations and Time.	h.	m.	Spring. Feet.	Neap. Feet.
COAST FROM EASTPORT TO NEW YORK.				
Eastport.........Me.	11	30	15	
Campo Bello*.... "	11		25	
Portland......... "	11	25	9.9	7.6
Cape Ann*....... "	11	30	11	
Portsmouth.....N.H.	11	23	9.9	7.2
Newburyport. Mass.	11	22	9.1	6.6
Salem.......... "	11	13	10.6	7.6
Cape Cod*...... "	11	30	6	
Boston Light ... "	11	12	10.9	8.1
Boston† .... "	11	27	10.3	8.5
Nantucket...... "	12	24	3.6	2.6
Edgartown ..... "	12	16	2.5	1.6
Holmes's Hole.. "	11	43	1.8	1.3
Tarpaulin Cove . "	8	4	2.8	1.8
Wood's Hole, n. side.	7	50	4.7	3.1
N. Bedford (Dumping Rock)	7	57	4.6	2.8
New York‡..... N.Y.	8	13	5.4	3.4
Albany*........ "	3	30	1	
LONG ISLAND SOUND.				
Newport........ R. I.	7	45	4.6	3.1
Point Judith..... "	7	32	3.7	2.6
Montauk Point.. N.Y.	8	20	2.4	1.8
Watch Hill ...... R.I.	9		3.1	2.4
Providence*..... "	8	25	5	
Stonington ....Ct.	9	7	3.2	2.2
Little Gull Isl'd. N.Y.	9	38	2.9	2.3
New London......Ct.	9	28	3.1	2.1
New Haven....... "	11	16	6.2	5.2
Bridgeport .... "	11	11	8	4.7
Oyster Bay..... N.Y.	11	7	9.2	5.4
Sand's Point.... "	11	13	8.9	6.4
New Rochelle... "	11	22	8.6	6.6
Throg's Neck... "	11	20	9.2	6.1
Hell Gate*...... "	9	35	6	
COAST OF NEW JERSEY.				
Cold Spring Inlet. N.J.	7	32	5.4	3.6
Sandy Hook......N.J.	7	29	5.6	4
Amboy.......... "	8	15	5	
Cape May Landing "	8	19	6	4.3
Egg Harbor*..... "	9	34	5	
...WARE BAY AND ...VER.				
...akwater	8		4.5	3
... May)..	8	33	6.2	3.9
...N.J.	9	4	7	5.1
...Del	[illegible]	53	6.9	6.6
			6.8	5.1

Locations and Time.	h.	m.	Spring. Feet.	Neap. Feet.
CHESAPEAKE BAY AND RIVERS.				
Old Pt. Comfort§..Va.	8	17	3	2
Cape Henry*..... "	7	51	6	
Point Lookout... Md.	12	58	1.9	.7
Annapolis....... "	17	4	1	.8
Bodkin Light.... "	18	8	1.3	.8
Baltimore....... "	18	59	1.5	.9
James R. (City Pt.), Va	14	37	3	2.5
Richmond........ "	16	58	3.4	2.3
COASTS OF N. AND S. CAROLINA, GEORGIA, AND FLORIDA.				
Hatteras Inlet .. N.C	7	4	2.2	1.8
Cape Hatteras ... "	9	1	5	
Beaufort .... "	7	26	3.3	2.2
Smithv'le (C. Fear) "	7	19	5.5	3.8
Charleston‖ (C. H. Wharf ...... S.C.	7	26	6	4.1
Fort Pulaski......Ga.	7	20	8	5.9
Savannah........ "	8	13	7.6	5.5
St. Augustine.... Fla.	8	21	4.9	3.6
Cape Florida .... "	8	84	1.8	1.2
Key West .... "	9	22	1.6	1
Tampa Bay ..... "	11	21	1.8	1
Cedar Keys...... "	13	15	3.2	1.6
WESTERN COAST.				
San Diego....... Cal.	9	38	5	2.3
San Pedro....... "	9	39	4.7	2.2
Cuyler's Harbor . "	9	25	5.1	2.8
San Luis Obispo.. "	10	8	4.8	2.4
Monterey........ "	10	22	4.3	2.5
South Farallone . "	10	37	4.4	2.8
San Francisco... "	12	6	4.3	2.8
Mare Island ..... "	13	40	5.2	4.1
Benicia .... "	14	10	5.1	3.7
Ravenswood..... "	12	36	7.3	4.9
Bodega.......... "	11	17	4.7	2.7
Humboldt Bay... "	12	2	5.5	3.5
Astoria...........Or.	12	42	7.4	4.6
Nee-ah Harbor, Wash.	12	33	7.4	4.8
Port Townshend "	3	49	5.5	4
MISCELLANEOUS.				
Bay of Fundy*..N.S.	12		60	
Blue Hill Bay*.. "	11		12	
St. John's*...... "	12		30	
Kingston*......Jam.	2	30	2	
Halifax*.........N. S.			7.5	.5
Pensacola*.......Fla.			1.5	.4
Galveston*......Tex.			1.6	.8

* ... of tide alone. † ‡ § ‖ see p. 85.

... mean lunar day) for some ports in Del... ...on the month; hence 12 h. 26 min. is ... that, to give the interval required.

Bench Marks referred to in preceding Table.

† BOSTON. — Top of wall or quay, at entrance to dry-dock in Charlestown navy-yard, 14.76 feet above mean low-water.

‡ NEW YORK. — Lower edge of a straight line, cut in a stone wall, at head of wooden wharf on Governor's Island, 14.56 feet above mean low-water.

§ OLD POINT COMFORT, Va. — A line cut in wall of light-house, one foot from ground, on southwest side, 11 feet above mean low-water.

‖ CHARLESTON, S. C. — Outer and lower edge of embrasure of gun No. 3, at Castle Pinckney, 10.13 feet above mean low-water.

Establishment of the Port for several Locations in Europe, etc.

PORT.	TIME.	PORT.	TIME.	PORT.	TIME.
	h. m.		h. m.		h. m.
Amsterdam	3	Chatham	1 2	Liverpool	11 16
Antwerp	4 25	Cherbourg	7 49	London Bridge	2 7
Beachy Head..Eng.	11 -	Clear Cape	4	Newcastle	1 22
Belfast	10	Cowes	10 46	Portsmouth D.-yard, Eng.	11 41
Bordeaux	6 50	Dover Pier	11 12	Quebec	8
Bremen	6	Dublin Bar	11 12	Ramsgate Pier	10 27
Brest Harbor	3 47	Funchal	11 30	Rye Bay ......Eng.	11 20
Bristol	7 21	Gravesend.....Eng.	1 14	Sheerness	57
Bristol Quay	6 27	Greenock	8	Sierra Leone	8 15
Cadiz	1 40	Holyhead	10 11	Southampton..Eng.	11 40
Calais	11 49	Hull..........Eng.	6 29	Thames R.,mo'th "	12
Calf of Man	11 5	Land's End	3 57	Woolwich ...... "	2 15
Cape St. Vincent	2 30	Lisbon	2 30		

Rise and Fall of Tides in Gulf of Mexico.

LOCATIONS.	Mean.	Spring.	Neap.	LOCATIONS.	Mean.	Spring.	Neap.
	Feet.	Feet.	Feet.		Feet.	Feet.	Feet.
St. George's Island....Fla.	1.1	1.8	.6	Isle Dernière..........La.	1.4	1.2	.7
Fort Morgan (Mobile Bay)............Ala.	1	1.5	.4	Entrance to Lake Calcasieu...........La.	1.5	1.1	.6
Cat Island..........Miss.	1.3	1.9	.6	Aransas Pass........ "	1.1	1.8	.6
Southwest Pass.......La.	1.1	1.4	.5	Brazos Santiago..... "	.9	1.2	.5

Tides of Gulf of Mexico.

On Coast of Florida, from Cape Florida to St. George's Island, near Cape San Blas, the tides are of the ordinary kind, but with a large daily inequality. From St. George's Island, Apalachicola entrance, to Dernière Isle, the tides are usually of the single-day class, ebbing and flowing but once in 24 (lunar) hours. At Calcasieu entrance, double tides reappear, and except for some days about the period of Moon's greatest declination, tides are double at Galveston, Texas. At Aransas and Brazos Santiago the single-day tides are as perfectly well marked as at St. George's, Pensacola, Fort Morgan, Cat Island, and the mouths of the Mississippi. For some 3 to 5 days, however, about the time when the Moon's declination is nothing, there are generally two tides at all these places in 24 hours, the rise and fall being quite small.

Highest high and lowest low waters occur when greatest declination of Moon happens at full or change. Least tides when Moon's declination is nothing at first or last quarter.

Tides of Pacific Coast.

On Pacific coast there is, as a general rule, one large and one small tide during each day, heights of two successive high-waters occurring, one A.M., and other P.M. of same 24 hours, and intervals from next preceding transit of Moon are very different. These inequalities depend upon Moon's declination. When Moon's declination is nothing, they disappear, and when it is greatest, either North or South, they are greatest. The inequalities for low water are not same as for high, though they disappear, and have greatest value at nearly same time.

When Moon's declination is North, highest of two high tides of the 24 hours occurs at San Francisco, about *11.5 hours after* Moon's southing (transit); and when declination is *South, lowest of the two high* tides occurs about this interval.

Lowest of two low-waters of the day is the one which follows next highest high water.

STEAMING DISTANCES.

Distances between various Ports of United States and Canada.

By Lake, River, and Canal.

Locations.	Lake and River.	Canal.	Total.	Locations.	Lake and River.	Canal.	Total.
	Miles.	Miles.	Miles.		Miles.	Miles.	Miles.
Duluth to Buffalo...	1024	1	1025	Chicago to New York,			
Chicago to Buffalo..	925	—	925	*via* Oswego.......	1195	232	1427
Duluth to Oswego...	1133	27	1160	Chicago to Montreal.	1190	71	1261
Chicago to Oswego..	1034	26	1060	Buffalo to Colborne,			
Duluth to New York,				*via* Welland Canal.	—	26.77	26.77
via Buffalo.....	1166	353	1519	Buffalo to New York.	142	352	494
via Oswego.....	1294	233	1527	Welland Canal to			
Duluth to Montreal.	1289	72	1361	Montreal..........	304.5	70.5	375
Chicago to New				Montreal to Kingston	126.25	120	246.25
York, *via* Buffalo.	1067	352	1419	Ottawa to Kingston.	—	126.25	126.25

Distances between various Ports and New York and London.

Not included in preceding Table.

Ports.	Miles. N.Y.	Miles. Lond.	Ports.	Miles. N.Y.	Miles. Lond.	Ports.	Miles. N.Y.	Miles. Lond.
Alexandria...	4893	3 102	Cape Race.....	1 004	2 249	New Orleans.	1790	4 730
Amsterdam..	3291	262	Cowes.........	3 092	200	Norfolk.....	308	3 447
Barbadoes...	1855	3 812	Funchal......	2 760	1 303	Pensacola...	1623	4 654
Batavia......	8972	11 492	Galway.......	2 720	721	Philadelphia.	262	3 404
Bermudas...	682	3 142	Gibraltar.....	3 260	1 325	Quebec	1360	3 080
Bombay.....	8522	10 703	Glasgow......	2 913	765	Queenstown.	2780	551
Boston......	356	3 030	Halifax.......	590	2 706	Rio Janeiro..	4970	5 200
Bremen......	3428	408	Havana.......	1 161	4 197	St. Johns....	1064	2 214
Bristol.......	2979	501	Hobart Town..	9 187	11 368	Southampton	3103	211
Buenos Ayres	6010	6 280	Kingston, Jam.	1 456	4 305	Swan River..	8480	10 661
Cadiz........	3125	1 115	Lima.........	10 050	10 149	Tortugas....	1151	4 182
Calcutta.....	9350	11 531	Madras.......	8 707	10 888	Washington.	461	3 612

Distances between various Ports of England, Canada, United States, etc.

Not included in preceding Table.

Ports.	Miles.	Ports.	Miles.	Ports.	Miles.
Halifax to		**Liverpool to**		**Panama to**	
Liverpool........	2 563	Havana...........	4100	San Diego........	2897
St. Thomas......	1 563	Portland..........	2770	Monterey..........	3198
St. Johns, N. F...	520	Baltimore.........	3400	San Francisco....	3240
Quebec to Glasgow.	2 563	**N. Orleans to Havana**	570	**San Francisco to**	
Liverpool to		**Cape Race to**		San Juan del Sud.	2685
Boston..........	2955	Fastnet..........	1711	Acapulco.........	1841
Quebec..........	2 855	Halifax...........	457	Manzanilla.......	1543
Philadelphia.....	3 147	Boston...........	835	San Diego........	474
Callao...........	11 379	**St. Johns, N. F., to**		Monterey.........	105
Fastnet..........	283	Quebec...........	891	Humboldt........	200
Cape Race........	1 992	Boston...........	890	Columbia R. Bar..	530
Aspinwall.......	4 650	Greenock.........	1848	Vancouver........	638
Port Said........	3 290	**Bermudas to Nassau.**	804	Portland..........	650
...ne.......	13 290	**Panama to**		Port Townshend ..	732
...ro......	5 125	San Juan del Sud.	570	Victoria..........	715
...sco...	13 800	Gulf of Fonseca...	739	Yokohama.......	4750
...a....	7 378	Acapulco.........	1416	Honolulu.........	2080
...opec	6 400	Manzanilla.......	1724	**Honolulu to Callao..**	5145

New York to	Nautical Miles.
Canton *via* Pacific R. R.	10 500
" " Panama	11 500
" " Suez Canal	11 500
Callao *via* Panama	3 500
San Blas *via* Panama	3 860
Yokohama *via* San Francisco,	8 102
Calcutta *via* Panama	13 400
Melbourne *via* Cape Horn	12 720
Minatitlan	1 962
Puerto Cabello (Honduras)	2 114
Cape Race	1 004
Aspinwall	2 000
Fernandina	830
Calcutta	17 500
Valparaiso†	12 900
Galway	2 371
Callao†	13 500
San Blas†	17 800
St. Thomas	1 563
Brest	3 000
Hamburg	3 590
Port Said	3 365
New Orleans to Tehuantepec	787
Aspinwall	1 400

London to	Nautical Miles.
Canton *via* Pacific R. R.	13 500
Canton *via* Suez Canal	10 000
Manila *via* Suez Canal	9 650
Hongkong *via* Yokohama	9 780
Queenstown	605
Bermuda	3 055
Rio de Janeiro	5 200
Port Said	3 365
Liverpool to	
Melbourne *via* Cape Horn	11 355
Southampton to Gibraltar	1 160
Rio de Janeiro	5 060
Hongkong to Yokohama	1 620
Shanghai	1 800
Honolulu	4 356

	Nautical Miles.
Shanghai to Yokohama	1210
Sydney to Cape Horn	5470
Aspinwall to Panama	51
Portsmouth to Jamaica	4050
Halifax to Galway	2165
Boston to Galway	2385

	St. Petersburg	Port Jackson	New York	New Orleans	Marseilles	London	Liverpool	Lisbon	Havre	Hamburg	Gibraltar	Copenhagen	Constantinople	Cape Horn	Cape of Good Hope	Canton	Batavia
San Francisco	15250†	6454	13610†	13980	13500†	13880†	13800†	12400†	13840†	14200†	12850†	14520†	14770†	6380	[illegible]	[illegible]	7650
St. Petersburg		13620	4100	6100	3400	1412	2060	2565	1560	1222	2653	730	4573	8880	7630	14670*	12870*
Port Jackson			12900†	13260†	11800*	12250*	12100	10690*	12120*	12550*	11110*	12890*	13020*	5663	5990	4680	3910
New York				1790	3850	3295	2986	2980	3068	3540	3260	3873	5100	7232	6790	16070†	12000*
New Orleans					5165	4730	4700	4370	4570	5030	4485	5370	6400	7600	7260	16440†	12470*
Marseilles						2036	1846	973	1896	2336	680	2676	1470	[illegible]	5800	12800*	11000*
London							689	1196	190	417	1358	682	3278	7510	6260	13300*	11500*
Liverpool								1010	550	992	1312	1329	3224	7400	6080	13100*	11310*
Lisbon									1040	1498	293	1835	2213	6020	4700	11700*	9900*
Havre										492	1189	830	3109	7460	6130	13140*	11340*
Hamburg											1657	492	3577	7810	6560	13600*	11800*
Gibraltar												1953	1920	6470	5123	12140*	10330*
Copenhagen													3673	8150	6900	13940*	12140*
Constantinople														8400	7040	14020*	12250*
Cape Horn															3610	8840†	8820* / 8720†
Cape of Good Hope																7000	5200
Canton																	1900

* Around Cape of Good Hope. † Around Cape Horn.

Distances between Principal Ports of United States, etc.

ILLUSTRATION OF TABLE.—Sandy Hook to New Orleans, 1677 miles.

Nautical Miles.

[illegible] Matamoras	1 969
" Coatzacoalcos	1 946
" New Orleans *via* Florida Canal	1 293
" Greytown	2 021
" Bermudas	680
" Nassau	962
" Panama	2 047
" " *via* Cape Horn	11 329
" Minatitlan	1 962
" Puerto Cabello (H.)	2 114
" Cape Race	1 004
New Orleans to Minatitlan	816
" " Puerto Cabello (H.)	945
" " Tampico	717
" " Galveston	379
" " Matamoras	580
" " Coatzacoalcos	806
" " Greytown	1 308
Fernandina to Cedar Keys	154
Pensacola to Tortugas	472

By Rivers Exclusively, in Statute Miles.

Pittsburg to Cincinnati	500
Cincinnati " Louisville	150
Louisville " Cairo	400
Cairo " St. Louis	180
St. Louis " Cincinnati	730
Cairo " Memphis	240
" " New Orleans	1040
Memphis " Vicksburg	400
" " Port Hudson	650
" " New Orleans	800
Louisville " " "	1450
Natchez " " "	320

By Land, in Statute Miles.

New York to San Francisco	3344
New Orleans to Cairo	548
St. Louis to Omaha	479
New York to Omaha	1393
New York to Galveston	1900

For relative distances by Statute miles between Western cities of U. S. and New York, Boston, etc., see Miscellaneous Notes, page 184, and for actual distances see page 187.

	Vera Cruz	New Orleans	Havana	Key West	Savannah	Charleston	Cape Hatteras	Richmond	Norfolk	Washington	Baltimore	Cape Henry	Philadelphia	Cape Henlopen	New York	Sandy Hook	Nantucket Light	Boston	Halifax
Halifax																			
Boston																			383
Nantucket Light																		103	365
Sandy Hook																	257	338	572
New York																18	275	356	590
Cape Henlopen															168	150	326	407	641
Philadelphia														94	262	244	420	501	735
Cape Henry													246	152	275	257	430	511	740
Baltimore												166	412	318	441	423	596	677	906
Washington											183	186	432	338	461	443	616	697	926
Norfolk										190	158	33	279	185	308	290	463	544	773
Richmond									101	275	223	129	375	281	404	386	559	640	869
Cape Hatteras								253	157	310	290	124	316	222	348	330	489	570	796
Charleston							265	527	431	584	564	398	597	503	623	605	761	842	1066
Savannah						98	341	603	507	660	640	474	673	579	699	681	837	918	1142
Key West					564	594	764	1026	930	1083	1063	897	1096	1002	122	1104	1260	1341	1552
Havana				71	609	639	809	1071	975	1128	1108	942	1141	1047	167	1149	1305	1386	1597
New Orleans			570	573	1137	1167	1337	1599	1503	1656	1636	1470	1669	1575	1790	1677	1833	1914	2125
Vera Cruz		782	877	859	1413	1443	1613	1875	1779	1932	1912	1746	1945	1851	1971	1953	2109	2190	2401
Puerto Bello	1558	1410	972	1142	1650	1643	1682	1928	1832	1985	1965	1799	1990	1896	2005	1987	2057	2138	2293

FRACTIONS.

. FRACTION, or broken number, is one or more parts of a UNIT.

LUSTRATION.—12 inches are 1 foot. Here, 1 *foot* is unit, and 12 *inches* its parts; *:hes* therefore, are *one fourth* of a foot, for 3 is fourth or quarter of 12.

. *Vulgar Fraction* is a fraction expressed by *two numbers* placed one ve the other, with a line between them; as, 50 cents is the $\frac{1}{2}$ of a dollar.

pper number is termed *Numerator*, the lower *Denominator*. *Terms* of a frac- express numerator and denominator; as, 6 and 9 are terms of $\frac{6}{9}$.

Proper fraction has numerator equal to, or less than denominator; as, $\frac{1}{4}$, etc.

1 *Improper* fraction is reverse of a proper one; as, $\frac{4}{3}$, etc.

Mixed fraction is a compound of a whole number and a fraction; as, $5\frac{7}{8}$, etc.

Compound fraction is fraction of a fraction; as, $\frac{1}{4}$ of $\frac{3}{4}$, etc.

Complex fraction is one that has a fraction for its numerator or denominator, oth; as, $\frac{\frac{1}{3}}{6}$, or $\frac{\frac{5}{3}}{4}$, or $\frac{2}{\frac{3}{4}}$, or $\frac{3\frac{1}{3}}{6}$, etc.

TE.—A Fraction denotes division, and its value is equal to quotient, obtained by ing numerator by denominator; thus, $\frac{12}{4}$ is equal to 3, and $\frac{21}{5}$ is equal to $4\frac{1}{5}$.

Reduction of Fractions.

Compute Common Measure or greatest Number hat will divide Two or more Numbers without a Remainder.

.E.—Divide greater number by less; then divide divisor by remainder; and so viding always last divisor by last remainder, until there is no remainder, and visor is greatest common measure required.

MPLE I.—What is greatest common re of 1908 and 936?

```
936) 1908 (2
     1872
       36) 936 (26
           72
           216.  Hence 36.
```

How many squares can there be obtained in an area of 90 by 160 feet?

1 10 is greatest common measure.

$$\text{Hence, } \frac{160}{10} = 16, \text{ and } \frac{90}{10} = 9;\ 16 \times 9 = 144, \text{ and } \frac{90 \times 160}{144} = 100.$$

Compute least Common Multiple of Two or more Numbers.

.—Divide given numbers by any number that will divide the greatest num- hem without a remainder, and set quotients with undivided numbers in a neath.

e second line in same manner, and so on, until there are no two numbers 1 be divided; then the continued product of divisors and last quotients will nmon multiple required.

PLE. — What is least 1 multiple of 40, 50,

```
5) 40 . 50 . 25
5)  8 . 10 .  5
2)  8 .  2 .  1
    4 .  1 .  1.  Then 5 × 5 × 2 × 4 × 1 × 1 = 200.
```

To Reduce a Fraction to its Lowest Term.

—Divide terms by any number or series of numbers that will divide them a remainder, or by their greatest common measure.

LE.—Reduce $\frac{720}{960}$ *of a foot to* its lowest terms.

$$\frac{720}{960} \div 10 = \frac{72}{96} \div 8 = \frac{9}{12} \div 3 = \frac{3}{4}, \text{ or 9 ins.}$$

H*

To Reduce a Mixed Fraction to its Equivalent, an Improper Fraction.

RULE.—Multiply whole number by denominator of fraction and to product add numerator; then set that sum above denominator.

EXAMPLE 1.—Reduce $23\frac{2}{6}$ to a fraction. $\frac{23\times6+2}{6}=\frac{140}{6}=\frac{70}{3}$.

2.—Reduce $\frac{123}{6}$ inches to its value in feet. $123\div6=20\frac{3}{6}=1$ *foot* $8\frac{1}{2}$ *ins.*

To Reduce a Complex Fraction to a Simple one.

RULE.—Reduce the two parts both to a simple fraction, multiply numerator of reduced fraction by denominator of reduced denominator, and denominator of numerator fraction by numerator of denominator fraction.

EXAMPLE.—Simplify complex fraction $\frac{2\frac{2}{3}}{4\frac{4}{5}}$. $\quad 2\frac{2}{3}=\frac{8}{3}$, $4\frac{4}{5}=\frac{24}{5}$ $\quad \frac{8\times5=40}{3\times24=72}=\frac{5}{9}$

To Reduce a Whole Number to an Equivalent Fraction having a given Denominator.

RULE.—Multiply whole number by given denominator, and set product over said denominator.

EXAMPLE.—Reduce 8 to a fraction, denominator of which shall be 9.

$8\times9=72$; then $\frac{72}{9}$ *result required.*

To Reduce a Compound Fraction to an Equivalent Simple one.

RULE.—Multiply all numerators together for a numerator, and all denominators together for a denominator.

NOTE.—When there are terms that are common, they may be cancelled.

EXAMPLE.—Reduce $\frac{1}{2}$ of $\frac{3}{4}$ of $\frac{2}{3}$ to a simple fraction.

$\frac{1}{2}\times\frac{3}{4}\times\frac{2}{3}=\frac{6}{24}=\frac{1}{4}$. Or, $\frac{1}{\cancel{2}}\times\frac{\cancel{3}}{4}\times\frac{\cancel{2}}{\cancel{3}}=\frac{1}{4}$, *by cancelling* 2's *and* 3's.

To Reduce Fractions of different Denominations to Equivalents having a Common Denominator.

RULE.—Multiply each numerator by all denominators except its own for new numerators; and multiply all denominators together for a common denominator.

NOTE.—In this, as in all other operations, whole numbers, mixed or compound fractions, must first be reduced to form of simple fractions.

2. When many of denominators are same, or are multiples of each other, ascertain their least common multiple, and then multiply the terms of each fraction by quotient of least common multiple divided by its denominator.

EXAMPLE.—Reduce $\frac{1}{2}$, $\frac{2}{3}$, and $\frac{3}{4}$ to a common denominator.

$$\left.\begin{array}{l}1\times3\times4=12\\2\times2\times4=16\\3\times2\times3=18\\\hline 2\times3\times4=24\end{array}\right\}=\frac{12}{24}=\frac{16}{24}=\frac{18}{24}, \text{ or } \frac{6}{12}, \frac{8}{12} \text{ and } \frac{9}{12}.$$

Addition.

RULE.—If fractions have a common denominator, add all numerators together, and place sum over denominator.

NOTE.—If fractions have not a common denominator, they must be reduced to ... Also, compound and complex must be reduced to simple fractions.

...LE 1.—Add $\frac{1}{4}$ and $\frac{3}{4}$ together. $\frac{1}{4}+\frac{3}{4}=\frac{4}{4}=1$.

... of $\frac{3}{4}$ of $\frac{6}{10}$ to $2\frac{1}{8}$ of $\frac{3}{4}$.

... $\times\frac{3}{4}\times\frac{6}{10}=\frac{18}{80}$. $2\frac{1}{8}$ of $\frac{3}{4}=\frac{17}{8}\times\frac{3}{4}=\frac{51}{32}$.

$\frac{51}{32}=\frac{4080}{2560}+\frac{576}{2560}=1\frac{131}{160}$, *reduced to equivalent fractions having ... inator and thence to its lowest terms.*

Subtraction.

LE.—Prepare fractions same as for other operations, when necessary; then act one numerator from the other, and set remainder over common denom-r.

AMPLE.—What is difference een $\frac{6}{8}$ and $\frac{3}{9}$?

$$\left.\begin{matrix} 6 \times 9 = 54 \\ 3 \times 8 = 24 \\ 8 \times 9 = 72 \end{matrix}\right\} = \frac{54}{72} - \frac{24}{72} = \frac{30}{72} = \frac{15}{36} = \frac{5}{12}.$$

Multiplication.

LE.—Prepare fractions as previously required; multiply all numerators to-er for a new numerator, and all denominators together for a new denominator.

AMPLE I.—What is product of $\frac{3}{4}$ and $\frac{3}{9}$? $\frac{3}{4} \times \frac{3}{9} = \frac{9}{36} = \frac{1}{4}$.

-What is product of 6 and $\frac{2}{3}$ of 5? $\frac{6}{1} \times \frac{2}{3}$ of $5 = \frac{6}{1} \times \frac{10}{3} = \frac{60}{3} = 20$.

Division.

LE.—Prepare fractions as before; then divide numerator by the numerator, enominator by the denominator, if they will exactly divide; but if not, invert erms of divisor, and multiply dividend by it, as in multiplication.

AMPLE I.—Divide $\frac{25}{9}$ by $\frac{5}{3}$. $\frac{25}{9} \div \frac{5}{3} = \frac{5}{3} = 1\frac{2}{3}$.

-Divide $\frac{5}{9}$ by $\frac{2}{15}$. $\frac{5}{9} \div \frac{2}{15} = \frac{5}{9} \times \frac{15}{2} = \frac{15}{9} \times \frac{5}{2} = \frac{75}{18} = \frac{25}{6} = 4\frac{1}{6}$.

Application of Reduction of Fractions.

Compute Value of a Fraction in Parts of a Whole Number.

E.—Multiply whole number by numerator, and divide by denominator; then, thing remains, multiply it by the parts in next inferior denomination, and by denominator, as before, and so on as far as necessary; so shall the quo-placed in order be value of fraction required.

MPLE I.—What is value of $\frac{1}{2}$ of $\frac{2}{3}$ of 9?

$$\frac{1}{2} \text{ of } \frac{2}{3} = \frac{2}{6}, \text{ and } \frac{2}{6} \times \frac{9}{1} = \frac{18}{6} = 3.$$

Reduce $\frac{3}{4}$ of a pound to an avoirdupois ounce.

4) 3 (0 *lbs.*
$\overline{16}$ *ounces in a lb.*
4) 48 (12 *ounces.*

Reduce a Fraction from one Denomination to another.

.—Multiply number of required denomination contained in given denomina-numerator *if reduction is to be to a less name*, but by denominator *if to a*

PLE I.—Reduce $\frac{1}{4}$ of a dollar to fraction of a cent.

$$\frac{1}{4} \times 100 = \frac{100}{4} = \frac{25}{1}.$$

educe $\frac{1}{6}$ of an avoirdupois pound to fraction of an ounce.

$$\frac{1}{6} \times 16 = \frac{16}{6} = \frac{8}{3} = 2\frac{2}{3}.$$

educe $\frac{2}{3}$ of $\frac{3}{4}$ of a mile to the fraction of a foot.

$$\frac{2}{3} \text{ of } \frac{3}{4} = \frac{6}{12} \times 5280 = \frac{31680}{12} = \frac{2640}{1}.$$

e of Three in Vulgar Fractions, see Decimals, page 94.

DECIMALS.

A DECIMAL is a fraction, having for its denominator a UNIT with as many ciphers annexed as the numerator has places; it is usually expressed by writing the numerator only, with a point at the left of it. Thus, $\frac{4}{10}$ is .4; $\frac{85}{100}$ is .85; $\frac{0075}{10000}$ is .0075; and $\frac{125}{100000}$ is .00125. When there is a deficiency of figures in the numerator, prefix ciphers to make up as many places as there are ciphers in denominator.

Mixed numbers consist of a whole number and a fraction; as, 3.25, which is the same as $3\frac{25}{100}$, or $\frac{325}{100}$.

Ciphers on right hand make no alteration in their value; for .4, .40, .400 are decimals of same value, each being $\frac{4}{10}$, or $\frac{2}{5}$.

Addition.

RULE.—Set numbers under each other according to value of their places, as in whole numbers, in which position the decimal points will stand directly under each other; then begin at right hand, add up all the columns of numbers as in integers, and place the point directly below all the other points.

EXAMPLE.—Add together 25.125 and 293.7325.

$$\begin{array}{r} 25.125 \\ \underline{293.7325} \\ 318.8575 \textit{ sum.} \end{array}$$

Subtraction.

RULE.—Set numbers under each other as in addition; then subtract as in whole numbers, and point off decimals as in last rule.

EXAMPLE.—Subtract 15.15 from 89.1759.

$$\begin{array}{r} 89.1759 \\ \underline{15.15} \\ 74.0259 \textit{ remainder.} \end{array}$$

Multiplication.

RULE.—Set the factors, and multiply them together same as if they were whole numbers; then point off in product just as many places of decimals as there are decimals in both factors. But if there are not so many figures in product, supply deficiency by prefixing ciphers.

EXAMPLE.—Multiply 1.56 by .75.

$$\begin{array}{r} 1.56 \\ \underline{.75} \\ 780 \\ \underline{1092} \\ 1.1700 \textit{ product.} \end{array}$$

By Contraction.

To Contract the Operation so as to retain only as many Decimal places in Product as may be required.

RULE.—Set unit's place of multiplier under figure of multiplicand, the place of which is same as is to be retained for the last in product, and dispose of the rest of figures in contrary order to which they are usually placed.

[illegible] multiplying, reject all figures that are more to right hand than each multiply[illegible]re, and set down the products, so that their right-hand figures may fall in a [illegible] directly below each other, and increase first figure [illegible] line with what would have arisen from figures [illegible] thus, add 1 for every result from 5 to 14, 2 from [illegible]m 25 to 34, 4 from 35 to 44, etc., and the sum [illegible]will be the product as required.

[illegible]y 13.57493 by 46.2051, and retain only [illegible] in the product.

$$\begin{array}{rl} 13.574\,93 & \\ \underline{1\,502.64} & \\ 54\,299\,72 & \\ 8\,144\,96 & +2 \textit{ for } 18 \\ 271\,50 & +2 \quad " \quad 18 \\ 6\,79 & +4 \quad " \quad 35 \\ \underline{14} & +1 \quad " \quad 5 \\ 627.23\,11 & \end{array}$$

[illegible] is required, increase last figure with what would have arisen from all the

Division.

RULE.—Divide as in whole numbers, and point off in quotient as many places for decimals as decimal places in dividend exceed those in divisor; but if there are not so many places, supply deficiency by prefixing ciphers.

EXAMPLE. Divide 53 by 6.75. 6.75) 53.000 00 (= 7.851+.

Here 5 ciphers are annexed to dividend to extend division.

By Contraction.

RULE.—Take only as many figures of divisor as will be equal to number of figures, both integers and decimals, to be in quotient, and ascertain how many times they may be contained in first figures of dividend, as usual.

Let each remainder be a new dividend; and for every such dividend leave out one figure more on right-hand side of divisor, carrying for figures cut off as in Contraction of Multiplication.

NOTE.—When there are not so many figures in divisor as there are required to be in quotient, continue first operation until number of figures in divisor are equal to those remaining to be found in quotient, after which begin the contraction.

EXAMPLE.—Divide 2508.928 06 by 92.410 35, so as to have only four places of decimals in quotient.

92.4103|5) 2508.928|06 (27.1498	13.849	912
1848 207 + 1	9 241	832 + 4
660 721	4 608	80
646 872 + 2	3 696	74 + 2
13 849	912	6

Reduction of Decimals.

To Reduce a Vulgar Fraction to its Equivalent Decimal.

RULE.—Divide numerator by denominator, annexing ciphers to numerator to extent that may be necessary.

EXAMPLE.—Reduce $\frac{4}{5}$ to a decimal. 5) 4.0
.8

To Compute Value of a Decimal in Terms of an Inferior Denomination.

RULE.—Multiply decimal by number of parts in next lower denomination, and cut off as many places for a remainder, to right hand, as there are places in given decimal.

Multiply that remainder by the parts in next lower denomination, again cutting off for a remainder, and so on through all the parts of integer.

EXAMPLE 1.—What is value of .875 dollars?

.875
100
Cents, 87.500
10
Mills, 5.000 = 87 *cents* 5 *mills*.

2.—What is volume of .140 cube feet in inches?

.140
1728 cube inches in a cube foot.
241.920 *cube ins.*

3.—What is value of .00129 of a foot? .01548 *ins.*

To Reduce a Decimal to an Equivalent Decimal of a Higher Denomination.

RULE.—Divide by number of parts in next higher denomination, continuing operation as far as required.

EXAMPLE 1.—Reduce 1 inch to decimal of a foot.

12 | 1.000 00
.083 33+ *foot*.

2.—Reduce 14″ 12‴ to decimal of a minute.

14″ 12‴
60
60 | 852.‴
60 | 14.2″
.236 66′+ *minute*.

When there are several numbers, to be reduced all to decimal of highest.
RULE.—Reduce them all to lowest denomination, and proceed as for one denomination.

EXAMPLE.—Reduce 5 feet 10 inches and 3 barleycorns to decimal of a yard.

Feet.	Ins.	Bc.
5	10	3
12		
70		
3		

3 | 213.
12 | 71.
3 | 5.9166
 | 1.9722+ *yards.*

Rule of Three.

RULE.—Prepare the terms by reducing vulgar fractions to decimals, compound numbers to decimals of the highest denomination, first and third terms to same denomination; then proceed as in whole numbers.

EXAMPLE.—If .5 of a ton of iron cost .75 of a dollar, what will .625 of a ton cost?

.5 : .75 :: .625
 .625
.5) .46875
 .9375, *dollar.*

DUODECIMALS.

In Duodecimals, or Cross Multiplication, the dimensions are taken in feet, inches, and twelfths of an inch.

RULE.—Set dimensions to be multiplied together one under the other, feet under feet, inches under inches, etc.

Multiply each term of multiplicand, beginning at lowest, by feet in multiplier, and set result of each immediately under its corresponding term, carrying 1 for every 12 from one term to the other. In like manner, multiply all multiplicand by inches of multiplier, and then by twelfth parts, setting result of each term one place farther to right hand for every multiplier. And sum of products will give result.

EXAMPLE.—How many square inches are there in a board 35 feet 4.5 inches long and 12 feet $3\frac{1}{3}$ inches wide?

Feet.	Ins.	Twelfths.		
35	4	6		
12	3	4		
424	6	0		
8	10	1	6	
	11	9	6	0
434	3	11	0	0

Value of Duodecimals in Square Feet and Inches.

	Sq. Ft.		Sq. Ins.
1 Foot .... =	1	or	144.
1 Inch .... =	$\frac{1}{12}$	"	12.
1 Twelfth .... =	$\frac{1}{144}$	"	1.

	Sq. Ft.		Sq. Ins.
$\frac{1}{12}$ of 1 twelfth =	$\frac{1}{1728}$	or	.083 333, etc.
$\frac{1}{12}$ of $\frac{1}{12}$ of " =	$\frac{1}{20736}$	"	.006 944, etc.

ILLUSTRATION.—What number of square inches are there in a floor 100 feet 6 inches long and 25 feet 6 inches and 6 twelfths broad?

2566 *feet* 11 *ins.* 3 *twelfths* = 2566 *feet* 135 *ins.*

MEAN PROPORTION.

MEAN PROPORTION is proportion to two given numbers or terms.

RULE.—Multiply two numbers or terms together, and extract square root of their product.

EXAMPLE.—*What is* mean proportionate velocity to 16 and 81?

$16 \times 81 = 1296$, and $\sqrt{1296} = 36$ mean velocity.

RULE OF THREE.

ULE OF THREE.—It is so termed because three terms or numbers are n to ascertain a fourth.

is either DIRECT or INVERSE.

is Direct when more requires more, or less requires less; thus, if 3 bar- of flour cost $18, what will 10 barrels cost?

this case Proportion is *Direct*, and stating must be,

As 3 : 10 :: 18 : 60.

is Inverse when more requires less, or less requires more; thus, if 6 men build tain quantity of wall in 10 days, in how many days will 8 men build like quan- Or, if 3 men dig 100 feet of trench in 7 days, in how many days will 2 men rm same work?

re the Proportion is *Inverse*, and stating must be,

As 8 : 6 :: 10 : 7.5, and 2 : 3 :: 7 : 10.5.

fourth term is always ascertained by multiplying 2d and 3d terms together, ividing their product by 1st term.

the three given numbers necessary for the stating, two of them contain the sition, and the third a demand.

E.—State question by setting down in a straight line the three necessary ers in following manner:

third term be that of *supposition*, of same denomination as the result, or 4th is to be, making *demanding* number 2d term, and the other number 1st term question is in *Direct Proportion*, but contrariwise if in *Inverse Proportion*; , let demanding number be 1st term.

tiply 2d and 3d terms together, and divide by 1st, and product will give re- r 4th term sought, of same denomination as 2d term.

.—If first and third terms are of different denominations, reduce them to same. If, after divis- re is any remainder, reduce it to next lower denomination, divide by divisor as before, and t will be of this last denomination.

etimes two or more statings are necessary, which may always be known by of question.

MPLE 1.—If 20 tons of iron cost $225, what will s cost?

Tons.	Tons.	Dolls.
20 :	500 ::	225
		500
	2|0)	11 250|0
		5 625 *dollars.*

A wall that is to be built to height of 36 feet, was raised 9 feet by 16 men in ; how many men could finish it in 4 days at same rate of working?

Days. Days. Men. Men.
4 : 6 :: 16 : 24

, if 9 feet requires 24 men, what will 27 feet require?

9 : 27 :: 24 : 72 *men.*

COMPOUND PROPORTION.

POUND PROPORTION is rule by means of which such questions as require two or more statings in simple proportion (Rule of Three) resolved in one.

le, however, is but little used, and not easily acquired, it is deemed prefer- omit it here, and to show the operation by two or more statings in Simple ion.

TRATION 1.—How many men can dig a trench 135 feet long in 8 ... can dig 54 feet in 6 days?

		Feet. Feet.	Men. Men.
First................	As	54 : 135 ::	16 : 40
		Days. Days.	Men. Men.
Second..............	As	8 : 6 ::	40 : 30

2.—If a man travel 130 miles in 3 days of 12 hours each, how many days of 10 hours each would he require to travel 360 miles?

		Miles.	Miles.		Days.	Days.
First..............	As	130 :	360	::	3 :	8.307+
		Hours.	Hours.		Days.	Days.
Second.............	As	10 :	12	::	8.307 :	9.9684

3.—If 12 men in 15 days of 12 hours build a wall 30 feet long, 6 wide, and 3 deep, in how many days of 8 hours will 60 men build a wall 300 feet long, 8 wide, and 6 deep? 120 *days.*

By Cancellation.

RULE.—On right of a vertical line put the number of same denomination as that of required answer.

Examine each simple proportion separately, and if its terms demand *a greater result than 3d term*, put *larger number on right and lesser on left of line;* but if its terms demand a *less result than 3d term*, put *smaller number on right and larger on left of line.*

Then *Cancel* the numbers divisible by a common divisor, and evolve the 4th term or result required.

Take Illustration 1, page 95: 3d term, or term of supposition of same denomination as required result, 16 *men.*

Statement.

	16
54	135
8	6

135 *feet* require more men than 54 *feet*, and 8 *days* less men than 6 *days.*

$$2 \times 5 \times 3 = 30 \textit{ men.}$$

Result by Cancellation.

	$\cancel{16}$ 2
2 $\cancel{54}$	$\cancel{135}$ 5
$\cancel{8}$	$\cancel{6}$ 3

ILLUSTRATION 3.—3d term, 15 *days.*

Statement.

	15
60	12
8	12
30	300
6	8
3	6

60 men require less days than 12 men, 8 hours more days than 12 hours, 300 feet more days than 30 feet, 8 feet more days than 6 feet, and 6 feet more days than 3 feet.

$$3 \times 4 \times 10 = 120 \textit{ days.}$$

Result by Cancellation.

	$\cancel{15}$
4 $\cancel{60}$	$\cancel{12}$ 3
$\cancel{8}$	$\cancel{12}$ 4
$\cancel{30}$	$\cancel{300}$ 10
$\cancel{6}$	$\cancel{8}$
$\cancel{3}$	$\cancel{6}$

INVOLUTION.

INVOLUTION is multiplying any number into itself a certain number of times. Products obtained are termed *Powers.* The number is termed the *Root*, or first power.

When a number is multiplied by itself once, product is *square* of that number; twice, *cube;* three times, *biquadrate;* etc. Thus, of the number 5.

5 *is the Root*, or 1st *power.*
$5 \times 5 = 25$ " *Square*, or 2d *power*, and is expressed 5^2.
$5 \times 5 \times 5 = 125$ " *Cube*, or 3d *power*, and is expressed 5^3.
$5 \times 5 \times 5 \times 5 = 625$ " *Biquadrate*, or 4th *power*, and is expressed 5^4.

The lesser figure set superior to number denotes the power, and is termed the *Index* or *Exponent.*

ILLUSTRATION 1.—What is cube of 9? 729.

2.—What is cube of $\frac{3}{4}$? $\frac{27}{64}$.

3.—What is 4th power of 1.5? 5.0625.

EVOLUTION.

EVOLUTION is ascertaining *Root* of any number.

$\sqrt{}$ placed before any number indicates that *square root* of that number is re-
r shown.

haracte any other root by placing the index above it.

$\sqrt{25} = 5$; $4 + 2 = \sqrt{36}$.
$\sqrt[3]{27} = 3$, and $\sqrt[3]{64} = 4$.

are termed Surd Roots.

To Extract Square Root.

—Point off given number from units' place, into periods of two figures each. tain greatest square in left-hand period, and place its root in quotient; sub- uare number from this period, and to remainder bring down next period vidend.

le this root for a divisor; ascertain how many times it is contained in divi- xclusive of right-hand figure, which, when multiplied by number to be put t hand of this divisor, product will be equal to, or next less than dividend; sult in quotient, and also at right hand of divisor.

ply divisor by last quotient figure, and subtract product from dividend; own next period, and proceed as before.

—Mixed decimals must be pointed off both ways from units.

PLE 1.—What is square root of 2?

```
  1| 2.000000 (1.41+.
  1| 1
 24|100
  4| 96
281| 400
  1| 281
282| 11900
```

2. What is square root of 144?

```
 1| 144 (12
 1| 1
22|044
  | 44
```

Square Roots of Fractions.

.—Reduce fractions to their lowest terms, and that fraction to a decimal, ceed as in whole numbers and decimals.

—When terms of fractions are squares, take root of each and set one above the other; as re root of $\frac{25}{36}$.

PLE.—What is square root of $\frac{9}{12}$? . .866 0254.

Compute 4th or 8th Root of a Number, etc.

—For the 4th root extract square root twice, and for 8th root thrice, etc.

To Extract Cube Root.

—From table of roots (page 272) take nearest cube to given number, and he assumed cube.

as given number added to twice assumed cube, is to assumed cube added given number, so is root of assumed cube to required root, *nearly;* and by like manner the root thus found as an assumed cube, and proceeding in ner, another root will be found still nearer; and in like manner as far as eemed necessary.

LE.—What is cube root of 10517.9?

t cube, page 272; 10648, root 22.

```
10648.      10517.9
    2             2
21296       21035.8
10517.9     10648.
31813.9  :  31683.8 :: 22 : 21.9+.
```

ertain or to Compute the Square or Cube Roots of ts, Whole Numbers, and of Integers and Decimals, Table of Squares and Cubes, and Rules, pp. 272, 300.

To Extract any Root whatever.

esent number.	Let A represent assumed power, r its root.
" index of the power.	R " required root of P.

sum of $n+1 \times A$ and $n-1 \times P$ is to sum of $n+1 \times P$ and $n-1 \times A$, ned root r to required root R.

ATION.—What is cube root of 1500?

cube, page 272, is 1331, root 11.

$$P = 1500,\ n = 3,\ A = 1331,\ r = 11;$$

$$\text{then, } n+1 \times A = 5324,\ n+1 \times P = 6000$$

$$n-1 \times P = 3000,\ n-1 \times A = 2662$$

$$8324 \qquad\qquad 8662.$$

I

To Compute the Root of an Even Power greater th any given in Table of Square and Cube Roots.

RULE.—Extract square or cube root of it, which will reduce it to half the gi power; then square or cube root of that power; and so on until required root is tained.

EXAMPLE 1.—Suppose a 12th power is given; the square root of that reduces i a 6th power, and the square root of 6th power to a cube.

2.—What is biquadrate, or 4th root, of 2 560 000?

$$\sqrt{2\,560\,000} = 1600, \text{ and } \sqrt{1600} = 40.$$

NOTE.—For other rules for extraction of roots see pp. 301–4.

PROPERTIES OF NUMBERS.

1. A *Prime Number* is that which can only be measured (divided without r mainder) by 1 or unity.
2. A *Composite Number* is that which can be measured by some number gre than unity.
3. A *Perfect Number* is that which is equal to the sum of all its divisors or quot parts; as $6 = \frac{6}{6}, \frac{6}{3}, \frac{6}{2}$.
4. If sum of the digits constituting any number be divisible by 3 or 9, the w is divisible by them.
5. A square number cannot terminate with an *odd* number of ciphers.
6. No square number can terminate with two equal digits, except two ciphe two fours.
7. No number, the last digit of which is 2, 3, 7, or 8, is a square number.

Powers of the first Nine Numbers.

1st.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	9th.
1	1	1	1	1	1	1	1	1
2	4	8	16	32	64	128	256	512
3	9	27	81	243	729	2 187	6 561	19 68
4	16	64	256	1 024	4 096	16 384	65 536	262 1
5	25	125	625	3 125	15 625	78 125	390 625	1 953 1
6	36	216	1296	7 776	46 656	279 936	1 679 616	10 077
7	49	343	2401	16 807	117 649	823 543	5 764 801	40 353
8	64	512	4096	32 768	262 144	2 097 152	16 777 216	134 217
9	81	729	6561	59 049	531 441	4 782 969	43 046 721	387 420

POSITION.

POSITION is of two kinds, SINGLE and DOUBLE, and it is determined number of SUPPOSITIONS.

Single Position.

RULE.—Take any number, and proceed with it as if it were the correct one; t as result is to given sum, so is supposed number to number required.

EXAMPLE 1.—A commander of a vessel, after sending away in boats $\frac{1}{3}$, $\frac{1}{6}$, a of his crew, had left 300; what number had he in command?

Suppose he had .... 600.

$\frac{1}{3}$ of 600 is 200
$\frac{1}{6}$ of 600 is 100
$\frac{1}{4}$ of 600 is 150   450

150 : 300 :: 600 : 1200 men.

2.—A person asked his age, replied, if $\frac{3}{4}$ of my age be multiplied by 2, and that product added to half the years I have lived, the sum will be 75. How old was he? *37.5 years.*

Double Position.

RULE.—Assume any two numbers, and proceed with each according to conditions of question; multiply results or *errors* by contrary supposition; that is, first position by last error, and last position by first error.

If errors are too great, mark them +; and if too little, —.

Then, if errors are *alike*, divide *difference* of products by *difference* of errors; but if they are *unlike*, divide *sum* of the products by *sum* of errors.

EXAMPLE 1.—A asked B how much his boat cost; he replied, that if it cost him 6 times as much as it did, and $30 more, it would have cost him $300. What was price of the boat?

Suppose it cost him	60	30
	6 *times.*	6 *times.*
	360	180
	and 30 *more*	and 30 *more*
	390	210
	300	300
	90+	90—
	30 *2d position.*	60 *1st position.*
90	2700	5400
90	5400	
180)	8100 (45 *dollars.*	

2.—What is length of a fish when the head is 9 inches long, tail as long as its head and half its body, and body as long as both head and tail? *6 feet.*

FELLOWSHIP.

FELLOWSHIP is a method of ascertaining gains or losses of individuals engaged in joint operations.

Single Fellowship.

RULE.—As the whole stock is to the whole gain or loss, so is each share to the gain or loss on that share.

EXAMPLE.—Two men drew a prize in a lottery of $9500. A paid $3, and B $2 for the ticket; how much is each share?

5 : 9500 :: 3 : 5700, A's *share.*
5 : 9500 :: 2 : 3800, B's *share.*

Double Fellowship,

Or Fellowship with Time.

RULE.—Multiply each share by time of its interest; then, as sum of products is to product of each interest, so is whole gain or loss to each share of gain or loss.

EXAMPLE.—A cutter's company take a prize of $10 000, which is to be divided according to their rate of pay and time of service on board. The officers have been on board 6 months, and the crew 3 months; pay of lieutenants is $100, ensigns $50 and crew $10 per month; and there are 2 lieutenants, 4 ensigns, and 50 men; what is each one's share?

2 lieutenants	$100 = 200 × 6 = 1200
4 ensigns	50 = 200 × 6 = 1200
50 men	10 = 500 × 3 = 1500
	3900

Lieutenants	*3900 : 1200 :: 10 000 :*	3076.92 ÷ 2 = 1538.46 dolls.
Ensigns	*3900 : 1200 :: 10 000 :*	3076.92 ÷ 4 = 769.23 "
Men	*3900 : 1500 :: 10 000 :*	3846.16 ÷ 50 = 76.92 "

PERMUTATION.

Permutation is a rule for ascertaining how many different ways any given number of numbers of things may be varied in their position.

Permutation of the three letters *abc*, taken *all together*, are 6; taken *two* and *two*, are 6; and taken *singly*, are 3.

Rule.—Multiply all the terms continually together, and last product will give result.

Example 1.—How many variations will the nine digits admit of?

$$1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8 \times 9 = 362\,880.$$

2.—How many years would there be required to elapse before 10 persons could be seated in a varied position collectively, each day at dinner, including one day in every 4 years for a leap year? 9935 *years*, 42 *days*.

When only part of the Numbers or Elements are taken at once. Rule.—Take a series of numbers, beginning with number of things given, decreasing by 1, until number of terms equals number of things or quantities to be taken at a time, and product of all the terms will give sum required.

Example 1.—How many changes can be made with 2 events in 5?

$5 - 1 = 4$, and $4 \times 5 = 2$ *terms*. Hence, $5 \times 4 = 20$ *changes*.

2.—How many changes of 2 will 3 playing cards admit of?

$3 - 1 = 2$, and $2 \times 3 = 2$ *terms*. Hence, $2 \times 3 = 6$ *changes*.

3.—How many changes can be rung with 4 bells (taken 4 and 4 together) out of 6?

$4 - 1 = 3$, and $3 \times 4 \times 5 \times 6 = 4$ *terms* or *changes*.
Hence, $3 \times 4 \times 5 \times 6 = 360$ *changes*.

When several of the Elements are alike. Rule.—Ascertain the permutations of all the numbers or things, and of all that can be made of each separate kind or division; divide number of permutations of whole by product of the several partial permutations, and quotient will give number of permutations.

Example.—How many permutations can be made out of the letters of the word persevere (9 letters, having 4 e's and 2 r's)?

$$1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8 \times 9 = 362\,880;$$
$1 \times 2 \times 3 \times 4 = 24$ for the e's; $1 \times 2 = 2$ for the r's, and $24 \times 2 = 48$.
Hence, $362\,880 \div 48 = 7560$.

Or, Add logarithms of all the terms together, and number for the sum will give result.

Example 1.—How many permutations can be made with three letters or figures?

Log. $1 = .00$
$2 = .301\,03$
$3 = .477\,121\,3$
$.778\,151\,3 =$ log. of number 6.

2.—How many variations will 15 numbers in 16 places admit of?

Add logarithms of numbers 1 to 16 and take logarithm of their sum—

viz., $13.320\,661\,97 = 20\,922\,789\,888\,000$.

Number of positions of the blocks in the "15 puzzle" is as above for their 16 permutations.

Permutations,

Whereby any questions of Permutation may be solved by Inspection, number of terms not exceeding 20.

9	362 880	13	6 227 020 800	17	355 687 428 096 000
[illegible]	3 628 800	14	87 178 291 200	18	6 402 373 705 728 000
[illegible]	39 916 800	15	1 307 674 368 000	19	121 645 100 408 832 000
[illegible]	479 001 600	16	20 922 789 888 000	20	2 432 902 008 176 640 000

ARITHMETICAL PROGRESSION.

[ETICAL PROGRESSION is a series of numbers increasing or de-y a constant number or difference; as, 1, 3, 5, 7, 12, 9, 6, 3. The which form the series are designated *Terms;* the first and last *Extremes*, and the others *Means*.

y three of following elements are given, the remaining two can be ascer-., *First* term, *Last* term, *Number* of terms, *Common Difference*, and *Sum* rms.

To Compute First Term.

st term, Number of terms, and Sum of series are given. RULE.—From twice sum of series, divided by number of terms, subtract last term.

; $\frac{S}{n} - \frac{d\,\overline{n-1}}{2}$; and $\sqrt{(l+.5\,d)^2-2\,d\,S} \pm .5\,d = a$. *a represent-t, n number of, and S sum of all terms, and d common difference.*

TION.—A man travelled 390 miles in 12 days, travelling 60 miles last day. l he travel first day?

$$\frac{390 \times 2}{12} = 65, \text{ and } 65 - 60 = 5 \textit{ first term.}$$

To Compute Last Term.

rst term, Common Difference, and Number of terms are given. RULE.—e number of terms less 1, by common difference, and to product add first

.—A man travelled for 12 days, at the rate of 5 miles first day, 10 second, how far did he travel the last day?

$$12 - 1 \times 5 = 55, \text{ and } 55 + 5 = 60 \textit{ miles.}$$

rst term, Number of terms, and Sum of series are given. RULE.—Divide of series by number of terms, and from quotient subtract first term.

$-a$; $\sqrt{2\,d\,S + (a - .5\,d)^2} \pm .5\,d$; and $\frac{S}{n} + \frac{d\,(n-1)}{2} = l$.

TION.—A man travelled 360 miles in 12 days, commencing with 5 miles ow far did he travel last day?

$$\frac{360 \times 2}{12} = 65, \text{ and } 65 - 5 = 60 \textit{ miles.}$$

To Compute Number of Terms.

mmon Difference and Extremes, or First and Last term, are given. ide difference of extremes by common difference, and add 1 to quotient.

.—A man travelled 3 miles first day, 5 second, 7 third, and so on, till he les in one day; how many days had he travelled at close of last day?

$$57 - 3 \div 2 = 27, \text{ and } 27 + 1 = 28 \textit{ days.}$$

m of series and Extremes are given. RULE.—Divide twice sum of series irst and last terms.

Or, $\frac{l-a}{d} + 1$; $\sqrt{\frac{2\,S}{d} + \left(\frac{2\,a-d}{2\,d}\right)^2} \pm \frac{d-2\,a}{2\,d}$;

and $\sqrt{\left(\frac{2\,l+d}{2\,d}\right)^2 - \frac{2\,S}{d}} \pm \frac{2\,l+d}{2\,d} =$

TION.—A man travelled 840 miles, walking 3 1 - last. many days was he travelling?

$$\frac{840 \times 2}{3 + 57} = \frac{1680}{60} = 28 \textit{ days.}$$

I*

To Compute Common Difference.

When Number of terms and Extremes are given. RULE.—Divide differ extremes by 1 less than number of terms.

$$\text{Or, } \frac{2\,S - 2\,an}{n\,(n-1)}; \quad \frac{l + a \times \overline{l-a}}{2\,S - l - a}; \quad \text{and } \frac{2\,nl - 2\,S}{n\,(n-1)} = d.$$

ILLUSTRATION.—Extremes are 3 and 15, and number of terms 7; what is c difference?

$$15 - 3 \div (7-1) = \frac{12}{6}, \text{ and } \frac{12}{6} = 2 \textit{ com. dif.}$$

To Compute Sum of the Series or of all Tern

When Extremes and Number of terms are given. RULE.—Multiply nur terms by half sum of extremes.

$$\text{Or, } 2\,a + \overline{d\,(n-1)} \times .5\,n; \quad \frac{l + a \times (l-a)}{2\,d} + \frac{l+a}{2};$$
$$\text{and } 2\,l - (d \times \overline{n-1}) \times .5\,n = S.$$

ILLUSTRATION.—How many times does hammer of a clock strike in 12 hou

$$12 \times \overline{12 + 1} = 156, \text{ and } 156 \div 2 = 78 \textit{ times.}$$

To Compute any Number of Arithmetical Mear Terms between two Extremes.

RULE. — Subtract less extreme from greater, and divide difference by than number of means or terms required to be ascertained, and then pro in rule.

To Compute Two Arithmetical Means or Terms bet two given Extremes.

RULE.—Subtract less extreme from greater, and divide difference by 3, q will be common difference, which being added to less extreme, or taken fror er, will give means.

EXAMPLE 1.—Compute two arithmetical means between 4 and 16.

$$16 - 4 \div 3 = 4 \textit{ com. dif.}$$
$$4 + 4 = 8 \textit{ one mean.}$$
$$16 - 4 = 12 \textit{ second mean.}$$

2.—Compute four arithmetical means between 5 and 30.

$$30 - 5 = 25, \text{ and } 25 \div \overline{4 + 1} = 5 = \textit{com. dif.}$$

$5 + 5 = 10 = $ *1st mean.*	$15 + 5 = 20 = $ *3d mean.*
$10 + 5 = 15 = $ *2d* "	$20 + 5 = 25 = $ *4th* "

Miscellaneous Illustrations.

1. A steamer having been purchased upon following terms — viz.: $50 transfer of bill of sale and balance in monthly instalments, commencing a for first month, and decreasing $500 in each month, until whole sum is paid

1st. How many months must elapse before final payment?

2d. What was amount of purchase-money, or sum of series?

Here are *first* and *last terms* — viz., 500 and 5000, and *common differen Hence,* To compute number of terms and amount of purchase,

$\overline{5000 - 500} \div 500 = 9$, and $9 + 1 = 10 =$ *number of terms or months,* ar

$$\frac{5000 + 500}{2} = 10 \times 2750 = \$27\,500, \textit{ amount of purchase.}$$

2. If 100 stones are placed in a right line, one yard apart; how many yar a person walk, to take them up one at a time and put them into a basket, o m first stone?

First term 2, last term 200, *and number of terms* 100.

$$\text{Hence, } 100 \times \frac{200 + 2}{2} = 10\,100 \text{ yards.}$$

3. If in the sinking of curb of a well, \$3 is to be given for first foot in depth, \$5 for second, \$7 for third, and increasing in like manner to a depth of 20 feet, what would it cost?

First term 3, *common difference* 2, *and number of terms* 20.

Hence, $20 - 1 \times 2 + 3 = 41$, *last term.*

$$\text{Then, } 3 + 41 \times \frac{20}{2} = 440, \textit{ sum of all terms, or cost of curb.}$$

4. If a contractor engaged to sink a curb to depth of 20 feet for \$400, and the contract was annulled when he had reached a depth of 8 feet; how much had he earned?

$400 \div 20 =$ *number of terms.* But inasmuch as 400 may be divided into 20 terms in arithmetical proportion in many different ways, according to value of 1st term, it becomes necessary to assume the value of the first foot as value of 1st term.

Assuming it at \$5, the required proportion will be, *1st term* 5, *number of terms* 20, *sum of series* 400.

$$\text{Hence, } \frac{400 - \overline{5 \times 20} \times 2}{20 \times (20 - 1)} = \frac{600}{380} = 1\tfrac{11}{19}, \textit{ common difference.}$$

Then, $5 + \overline{1\frac{11}{19} \times 7} = 16\frac{1}{19} =$ *1st term + product of common difference and* 8th *term less* 1, which added to $5 = 21\frac{1}{19}$, and $\times\, 4 =$ *half number of terms for which cost is sought* $= 84\frac{4}{19}$ *dollars, sum earned.*

GEOMETRICAL PROGRESSION.

Geometrical Progression is any series of numbers continually increasing by a constant multiplier, or decreasing by a constant divisor, as 1, 2, 4, 8, 16, etc., and 15, 7.5, 3.75, etc.

The constant multiplier or divisor is the *Ratio.*

When any three of following elements are given, remaining two can be computed, viz.: *First* term, *Last* term, *Number* of Terms, *Ratio,* and *Sum* of all Terms.

To Compute First Term.

When Ratio, Last Term, and Number of Terms are given. Rule. — Divide last term by ratio raised to a power denoted by number of terms less 1.

Or, $\frac{S\,(r-1)}{r^n - 1}$ and $r\,l - S\,(r-1) = a$. *a representing* 1st *term, l last, n number of,* S *sum of all terms, and r ratio.*

Illustration. — Last term is 4374, number of terms 8, and ratio 3; what is first term?

$$\frac{4374}{3^{8-1}} = \frac{4374}{2187} = 2, \textit{ first term.}$$

To Compute Last Term.

When First Term and Ratio are Equal. Rule.—Write a few of leading terms of series and place their indices over them, beginning with a unit. Add together the most convenient and least number of indices to make the index to term required. Multiply terms of the series of these indices together, and product will give term required.

Or, Multiply first term by ratio raised to a power, denoted by number of terms less 1.

Example 1.—First term is 2, ratio 2, and number of terms 13; what is last term?

Indices,	1	2	3	4	5
Terms,	*2,*	*4,*	*8,*	*16,*	*32.*

Then, $5 + 5 + 3 = 13 =$ *sum of indices,* and $32 \times 32 \times 8 = 8192 =$ *last term.*

Or, $2 \times 2^{13-1} = 8192$. *Also by inspection of table, page* 105, 13th term = 81[illegible]

2.—The price of 12 horses being 4 cents for first, 16 for second, and 64 for third, and so on; what is price of last horse?

Indices, 1 2 3 4
Terms, 4, 16, 64, 256.

Then, $4+4+4=12=$ *sum of indices*, and $256\times256\times256=256^3=\$167$ [illegible]

When First Term and Ratio are Different. RULE.—Write a few of leading terms of series, and place their indices over them, beginning with a cipher. Add together the most convenient indices to make an index less by 1 than term sought.

Multiply terms of these series belonging to these indices together, and take product for a dividend.

Or, Raise first term to a power, index of which is 1 less than number of terms multiplied; take result for a divisor; proceed with their division, and quotient will give term required.

EXAMPLE 1.—First term is 1, ratio 2, and number of terms 23; what is the last term?

Indices, 0 1 2 3 4 5
Terms, 1, 2, 4, 8, 16, 32.

Then, $5+5+5+5+2=22=$ *sum of indices*, and $32\times32\times32\times32\times4=4\,194\,304$, and $4\,194\,304\div$ the 5th power $(6-1)$ of $1=1=4\,194\,304$.

Or, $1\times2^{23-1}=4\,194\,304$. By inspection of table, page 105, 23d term $=4\,194\,304$.

2.—If 1 cent had been put out at interest in 1630, what would it have amounted to in 1834, if it had doubled its value every 12 years?

$1834-1630=204$, which $\div 12=17$, and $17+1=18=$ *number of terms.*

Indices, 0 1 2 3 4 7
Terms, 1, 2, 4, 8, 16, 128.

Then, $7+4+3+2+1=17$, and $128\times16\times8\times4\times2\times1=131\,072$, and $131\,072\div1$, the 4th power $(5-1)$ of $1=\$1310.72$.

When First Term, Ratio, and Sum of the series are given. RULE.—From sum of series subtract quotient of first term subtracted from sum of series, divided by ratio.

$$\text{Or, } a\times r^{n-1}=l.$$

EXAMPLE.—First term is 2, ratio 3, and sum of series 2186; what is last term?

$$2186-\frac{2186-2}{3}=2186-728=1458, \textit{ last term.}$$

To Compute Number of Terms.

When Ratio, First, and Last Terms are given. RULE.—Divide logarithm of quotient of product of ratio and last term, divided by first term, by logarithm of ratio.

$$\text{Or, }\frac{\log.(a+S\,\overline{r-1})-\log.a}{\log.r};\qquad\frac{\log.l-\log.a}{\log.(S-a)-\log.(S-l)}+1;$$

$$\text{and }\frac{\log.l-\log.(r\,l-\overline{r-1}\,S)}{\log.r}+1=n.$$

EXAMPLE.—Ratio is 2, and first and last terms are 1 and 131 072; what is number of terms?

$$\log.\frac{2\times131\,072}{1}=\log.262\,144=5.418\,54, \text{ and } 5.418\,54\div\log.\text{ of }2=\frac{5.418\,54}{.301\,03}=18.$$

To Compute Sum of Series.

When First Term, Ratio, and Number of Terms are given. RULE.—Raise ratio to power index of which is equal to number of terms, from which subtract 1; then divide remainder by ratio less 1, and multiply quotient by first term.

$$\frac{l^{n-1}\sqrt{l}-a^{n-1}\sqrt{a}}{\sqrt[n-1]{l}-\sqrt[n-1]{a}}\text{ and }\frac{l\,\overline{r^n-1}}{\overline{r-1}\,r^{n-1}}=S.$$

STRATION 1.—First term is 2, ratio 2, and number of terms 13; what is sum s?

$-1 = 8192 - 1 = 8191$, and $8191 \div (2-1) = 8191$, and $8191 \times 2 = 16\,382$.

If a man were to buy 12 horses, giving 2 cents for first horse, 6 cents for , and so on, what would they cost him? $5314.40.

To Compute Ratio.

First Term, Last Term, and Numbers of Terms are given. RULE.—Divide m by first, and quotient will be equal to ratio raised to power denoted by 1 n number of terms; then extract root of this quotient.

$$\text{Or, } \frac{S-a}{S-l} = r.$$

TRATION.—First term is 2, last term 4374, and number of terms 8; what is

$$\frac{4374}{2} = 2187, \text{ and } \sqrt[8-1]{2187} = 3, \textit{ ratio.}$$

Miscellaneous Illustrations.

at is 9th term in geometrical progression 3, 9, 27, 81, etc.? and what is erms?

1st term = 3, number of terms 9, and ratio 3.

, by rule to compute last term, 1st term and ratio being equal—

Indices, 1 2 3 4
Terms, 3, 9, 27, 81.

$2+3+4 = 9 =$ *sum of indices*, and $9 \times 27 \times 81 = 19\,683 =$ *last term.*

to compute sum of terms—

$$\frac{3^9 - 1}{3-1} \times 3 = \frac{19\,682}{2} = 9841 \times 3 = 29\,523, \textit{ sum of terms.}$$

t term is 1, ratio 2, and last term 131 072; what is sum of series?

$$131\,072 \times 2 - 1 = 262\,143, \text{ and } 262\,143 \div \overline{2-1} = 262\,143.$$

t are the proportional terms between 2 and 2048?

$$4+2 = 6, \text{ and } 6-1 = 5, \text{ and } \sqrt[5]{\frac{2048}{2}} = 4.$$

Hence, 2 : 8 : 32 : 128 : 512 : 2048.

of series is 6560, ratio 3, and number of terms 8; what is first term?

$$6560 \times \frac{3-1}{3^8-1} = 6560 \times \frac{2}{6560} = 2, \textit{ first term.}$$

Geometrical Progressions,

ny questions of Geometrical Progression and of Double Ratio may be solved by Inspection, number of terms not exceeding 56.

15	16 384	29	268 435 456	43	4 398 046 511 104
16	32 768	30	536 870 912	44	8 796 093 022 208
17	65 536	31	1 073 741 824	45	17 592 186 044 416
18	131 072	32	2 147 483 648	46	35 184 372 088 832
19	262 144	33	4 294 967 296	47	70 368 744 177 664
20	524 288	34	8 589 934 592	48	140 737 [illegible]
21	1 048 576	35	17 179 869 184	49	281 47 [illegible]
22	2 097 152	36	34 359 738 368	50	562 9 [illegible]
23	4 194 304	37	68 719 476 736	51	1 125 8 [illegible]
24	8 388 608	38	137 438 953 472	52	2 251 7 [illegible]
25	16 777 216	39	274 877 906 944	53	4 503 5 [illegible]
26	33 554 432	40	549 755 813 888	54	9 007 1 [illegible]
27	67 108 864	41	1 099 511 627 776	55	18 014 [illegible]
28	134 217 728	42	2 199 023 255 552	56	36 028 7 [illegible]

TIONS.—12th power of $2 = 4096$, and 7th root of $128 = 2$.

ALLIGATION.

ALLIGATION is a method of finding mean rate or quality of different materials when mixed together.

To Compute Mean Price of a Mixture.

When Prices and Quantities are known. RULE.—Multiply each quantity by its rate, divide sum of products by sum of quantities, and quotient will give rate of the composition.

EXAMPLE.—If 10 lbs. of copper at 20 cents per lb., 1 lb. of tin at 5 cents, and 1 lb. of lead at 4 cents, be mixed together, what is value of composition?

$$\begin{array}{r} 10 \times 20 = 200 \\ 1 \times 5 = 5 \\ 1 \times 4 = 4 \\ \hline 12 \quad) \; 209 \end{array} \; (17.416 \textit{ cents.}$$

To Compute Quantity of each Article.

When Prices and Mean Price are given. RULE.—Write prices of ingredients, one under the other in order of their values, beginning with least, and set mean price at left. Connect with a line each price that is *less* than mean rate with one or more that is *greater*.

Write difference between mixture rate and that of each of simples opposite price with which it is *connected;* then sum of differences against any price will express quantity to be taken of that price.

EXAMPLE.—How much gunpowder, at 72, 54, and 48 cents per pound, will compose a mixture worth 60 cents a pound?

$$60 \left\{ \begin{array}{l} 48 \\ 54 \\ 72 \end{array} \right. \quad \begin{array}{r} 12, \text{ at } 48 \textit{ cents.} \\ 12, \text{ at } 54 \textit{ cents.} \\ 12 + 6 = 18, \text{ at } 72 \textit{ cents.} \end{array}$$

Here, $72 - 60 = 12$ at 48, $72 - 60 = 12$ at 54, $60 - 48 = 12$, and $60 - 54 = 6 = 12 + 6 = 18$ at 72.

Then $12 \times 48 + 12 \times 54 + 18 \times 72 = 2520$, and $2520 \div \overline{12 + 12 + 12 + 6} = 60$ *cents.*

NOTE.—Should it be required to mix a definite quantity of any one article, the quantities of each, determined by above rule, must be increased or decreased in proportion they bear to defined quantity.

Thus, had it been required to mix 18 pounds at 48 cents, result would be 18 at 48, 18 at 54, and 27 at 72 cents per pound.

When the whole Composition is limited. RULE.—As sum of relative quantities, as ascertained by above rule, is to whole quantity required, so is each quantity so ascertained to required quantity of each.

EXAMPLE.—Required 100 pounds of above mixture

Then, $12 + 12 + 18 = 42$. Then, $42 : 100 :: 12 : 28.571$ *pounds.*
$42 : 100 :: 12 : 28.571$ *pounds.*
$42 : 100 :: 18 : 42.857$ *pounds.*

When Price of Several Articles and Quantity of one of them is given. RULE.—Ascertain proportionate quantities of ingredients by previous rule.

Then, as number opposite ingredients, quantity of which is given, is to given quantity; so is number opposite to each ingredient to quantity required of that ingredient.

EXAMPLE.—Having 35 lbs. of tobacco, worth 60 cents per pound, how much of other qualities, worth 65, 70, and 75 cents per pound, must be mixed with it, so as to sell mixture at 68 cents per pound?

By previous rule, it is ascertained there must be 7 lbs. at 60, 2 at 65, 3 at 70, and 8 at 75 cents; but as there are 35 lbs. at 60 cents to be taken, other quantities and kinds must be increased in like manner.

Hence, $7 : 35 :: 2 : 10 = 10$ at 65 *cents.*
$7 : 35 :: 3 : 15 = 15$ " 70 cents.
$7 : 35 :: 8 : 40 = 40$ " 75 cents.

SIMPLE INTEREST.

pute Interest on any Given Sum for a Period of One or more Years.

ıltiply given sum or *principal* by rate per cent. and number of years; figures to right of product, and result will give interest in dollars and ear.

—What is interest upon $ 1050 for 5 years at 7 per cent.?

$$1050 \times 7 \times 5 = 36\,750, \text{ and } 367.50 = \$\,367.50.$$

ıe is less than One Year. RULE.—Proceed as before, multiplying by nonths or days, and dividing by following units—viz., 12 for months, 66, as the case may be, for days.

—What is interest upon $1050 for 5 months and 30 days at 7 per cent.?

and 30 days = 183 *days.* $\frac{1050 \times 7 \times 183}{365} = 3685$, and $36.85 = \$\,36.85$.

tion of computing interest may be performed thus:

interest upon any sum at 6 per cent. = 1 per cent. for 2 months.

5 per cent. is $\frac{1}{6}$th less than at 6 per cent.

7 per cent. is $\frac{1}{6}$th greater than at 6 per cent.

ɔceding example—2 months = 1 per cent. = 10.50

2	"	= 1	"	10.50
1	"	= $\frac{1}{2}$	"	5.25
30 days		= 1 month		= 5.25
				31.50
Add $\frac{1}{6}$ for 7 per cent. =				5.25
				$36.75

ırence between this amount and preceding arises from 183 days being taken in one case, ', or 182.5 days, in the other.

ɔomputation of interest there are four elements—viz., Principal, Time, ıterest or Amount, any three of which being given, remaining one can ed.

To Compute Principal.

ıe, Rate per Cent., and Interest are given. RULE.—Divide given interest ɔf $1, etc., for given rate and time.

—What sum of money at 6 per cent. will in 14 months produce $ 14?

$$14 \div .07 = 200 \text{ } \textit{dollars.}$$

To Compute Rate per Cent.

incipal, Interest, and Time are given. RULE.—Divide given interest by ,iven sum, for time, at 1 per cent.

—If $ 32.66 was discounted from a note of $ 400 for 14 months, what r cent.?

n 400 for 14 months at 1 per cent. = 4.66.

Then $32.66 \div 4.66 = 7$ *per cent.*

To Compute Time.

incipal, Rate per Cent., and Interest are given. RULE.—Divide given interest of sum, at rate per cent. for one year.

—In what time will $ 108 produce $ 11.34, at 7 per cent.?

n 108 for one year is 7.56.

$$11.34 \div 7.56 = 1.5 \text{ } \textit{years.}$$

TION 1.—*If an amount of $ 2175* is returned for a peri *est having been 7 per cent.*, what was principal inves

o in 18 months will produce $ 1090, what is rate?

COMPOUND INTEREST.

If any Principal be multiplied by number (in following table) opposite years, and under rate per cent., sum will be amount of that principal at compound interest for time and rate taken.

EXAMPLE.—What is amount of $500 for 10 years at 6 per cent.?

Tabular number.... 1.790 84, and 1.790 84 × 500 = 895.42 *dollars.*

Years.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.	Years.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.
1	1.03	1.04	1.05	1.06	13	1.468 53	1.665 07	1.885 64	2.132 98
2	1.0609	1.081 6	1.102 5	1.123 6	14	1.515 29	1.731 67	1.979 93	2.2609
3	1.092 73	1.124 86	1.157 62	1.191 01	15	1.557 97	1.800 95	2.078 92	2.396 55
4	1.125 51	1.169 86	1.215 5	1.262 47	16	1.604 71	1.872 98	2.182 87	2.540 35
5	1.159 27	1.216 68	1.276 98	1.338 22	17	1.652 85	1.947 99	2.292 01	2.692 77
6	1.194 05	1.265 32	1.34	1.418 51	18	1.702 44	2.025 81	2.406 61	2.854 33
7	1.229 87	1.315 93	1.407 1	1.503 63	19	1.753 5	2.106 84	2.526 95	3.025 59
8	1.266 77	1.368 57	1.477 45	1.593 84	20	1.806 11	2.191 13	2.653 29	3.207 13
9	1.304 77	1.423 31	1.551 32	1.689 47	21	1.860 29	2.278 76	2.785 96	3.399 56
10	1.343 92	1.480 24	1.628 89	1.790 84	22	1.916 1	2.369 92	2.925 26	3.603 53
11	1.384 24	1.539 45	1.710 33	1.898 29	23	1.973 6	2.464 21	3.071 52	3.819 74
12	1.425 76	1.601 03	1.795 85	2.012 19	24	2.032 79	2.563 3	3.225 09	4.048 73

For any other Rate or Period.—Multiply logarithm of rate + 1 by period, and number for logarithm will give tabular amount as above.

ILLUSTRATION.—What is tabular number for 4 per cent. for 10 years?

Log. of 1.04 = .017 033 3, which × 10 = .170 333, and number for log. = 1.48024.

Time in Years in which a Sum of Money will be doubled at Several Rates of Interest.

Rate.	Time.	Rate.	Time.	Rate.	Time.	Rate.	Time.
Per cent.		Per cent.		Per cent.		Per cent.	
1	69.68	4	17.67	7	10.34	10	7.27
2	35	5	14.21	8	9.01	20	3.8
3	23.44	6	11.88	9	8.04	30	2.64

Value of $1, etc., Computed Semi-annually for a Period of 12 Years.

Years.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.	Years.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.
.5	1.015	1.02	1.025	1.03	6.5	1.2134	1.2936	1.3785	1.4684
1	1.0302	1.0404	1.0506	1.0609	7	1.2317	1.3195	1.413	1.5102
1.5	1.0457	1.0612	1.0769	1.0927	7.5	1.2502	1.3459	1.4483	1.558
2	1.0614	1.0824	1.1038	1.1255	8	1.269	1.3728	1.4845	1.6047
2.5	1.0773	1.1041	1.1314	1.1593	8.5	1.288	1.4002	1.5216	1.6528
3	1.0934	1.1262	1.1597	1.1941	9	1.3073	1.4282	1.5597	1.7024
3.5	1.1098	1.1487	1.1887	1.2299	9.5	1.3269	1.4568	1.5987	1.7535
4	1.1265	1.1717	1.2184	1.2668	10	1.3469	1.486	1.6386	1.8061
4.5	1.1434	1.1951	1.2489	1.3048	10.5	1.3671	1.5157	1.6796	1.8603
5	1.1604	1.219	1.2801	1.3439	11	1.3876	1.546	1.7216	1.9161
5.5	1.178	1.2434	1.3121	1.3842	11.5	1.4084	1.5769	1.7606	1.9736
6	1.1956	1.2689	1.3449	1.4258	12	1.4295	1.6084	1.8087	2.0356

ILLUSTRATION.—What is amount of $500 at semi-annual interest of 5 per cent. compounded for 10 years?

Tabular number 1.6386. Then, 500 × 1.628 89 = $ 814.44.5.

To Compute Interest on any Given Sum.

a Period of Years. $P(1+r)^n = A$; $\frac{A}{(1+r)^n} = P$; $\sqrt[n]{\frac{A}{P}} - 1 = r$.

— $\frac{\text{log. P}}{r1} = n$. *P representing principal, r rate per cent. per annum,* ...

...*unt of principal and interest.*

STRATION.—Assume as preceding, \$500 at 5 per cent. for 10 years.

$< 1.05^{10} = 500 \times 1.628\,89 = \$814.44.5$, *amount*. $\frac{814.44.5}{(1+.05)^{10}} = 500$, *principal*.

$\frac{.44.5}{.00} - 1 = .05$, *rate*. $\frac{\log. 814.44.5 - \log. 500}{\log. (1+.05)} = 10$, *number of years*.

any Period.—Assume elements of preceding case, interest payable semi-ly. $10 \times 2 = 20$, *number* of payments; $\frac{.05}{2} = .025$, *rate*.

Then, $500 \times 1.025^{20} = 500 \times 1.638\,62 = \$\,819.31$.

n term of payments and rate are not given in table.

$$\left[\log. \left(\frac{r}{2}+1\right) \times n\,P\right] = \log. A.$$

STRATION.—Assume \$1000 for 30 years, at 7 per cent. half-yearly.

$\log. \frac{.07}{2} + 1 = .014\,940\,3$, and $\log. \overline{.014\,940\,3 \times 30} \times 1000 = \$\,2806.78$.

DISCOUNT OR REBATE.

COUNT or REBATE is a deduction upon money paid before it is due.

To Compute Rebate upon any Sum.

:—Multiply amount by rate per cent. and by time, and divide product by product of rate per cent. and time, added to 100.

IPLE 1.—What is discount upon \$12 075 for 3 years, 5 months, and 15 days, r cent. ?

3 years 5 months and 15 days = 3.4574 *years*.

$$\frac{12\,075 \times 6 \times 3.4574}{100 + (6 \times 3.4574)} = \frac{250\,488.63}{120.7444} = 2074.53 = \$\,2074.53.$$

That is present value of a note for \$963.75, payable in 7 months, at 6 per

7 months $= \frac{7}{12}$ of 1 year $= 6 \times 7 \div 12 = 3.5$, and $3\,5 + 100 = 103.5 \div 100 = 1.035$. $963\,75 \div 1\,035 = \$931.16$

mpute the Sum for a given Time and Rate, to yield a Certain Sum.

—Divide given sum by proceeds of \$1 for given time and rate.

LE.—For what sum should a note be drawn at 90 days, that when dis- at 6 per cent. it will net \$200?

Discount on \$1 for 90 + 3 days at 6 per cent. = \$.0155.

Hence, \$1 — .0155 = .9845, *proceeds*, and \$200 ÷ .9845 = \$203.14.9.

EQUATION OF PAYMENTS.

-Multiply each sum by its time of payment in days, and divide sum of by sum of payments.

LE.—A owes B \$300 in 15 days, \$60 in 12 days, and \$350 in 20 ds ole due?

$$\begin{array}{r} 300 \times 15 = 4\,500 \\ 60 \times 12 = 720 \\ \underline{350} \times 20 = \underline{7\,000} \\ 710 \quad)\; \overline{12\,220}\; (17+ \textit{days}. \end{array}$$

ANNUITIES.

To Compute Amount of Annuity.

When Time and Ratio of Interest are Given. RULE.—Raise the *ratio* to a power denoted by time, from which subtract 1; divide remainder by *ratio* less 1, and quotient, multiplied by annuity, will give amount.

NOTE.—$1 added to given rate per cent. is ratio, and preceding table in Compound Interest is a table of ratios.

EXAMPLE.—What is amount of an annual pension of $100, interest 5 per cent, which has remained unpaid for four years?

1.05 ratio; then $1.05^4 - 1 = 1.215\,506\,25 - 1 = .215\,506\,25$, and $.215\,506\,25 \div (1.05 - 1) .05 = 4.310\,125$, which $\times\ 100 =$ $431.01.25.

To Compute Present Worth of an Annuity.

When Time and Rate of Interest are Given. RULE.—Ascertain amount of it for whole time; divide by ratio, involved to time, and result will give worth.

EXAMPLE.—What is present worth of a pension or salary of $500, to continue 10 years at 6 per cent. compound interest?

$500, by last rule, is worth $6590.3975, which, divided by 1.06^{10} (by table, page 108, is 1.790 84) = $3680.05.

Or, Multiply tabular amount in following table by given annuity, and product will give present worth.

ILLUSTRATION 1.—As above; 10 years at 6 per cent. = 7.360 08, and $7.360\,08 \times 500 = 3680.04$ *dollars.*

2. What is present worth of $150 due in one year at 6 per cent. interest per annum?

$.943\,39 \times 150 =$ $141.50.85.

Present Worth of an Annuity of $1, at 4, 5, and 6 Per Cent. Compound Interest for Periods under 25 Years.

Years.	4 Per Cent.	5 Per Cent.	6 Per Cent.	Years.	4 Per Cent.	5 Per Cent.	6 Per Cent.
1	.961 54	.952 38	.943 39	13	9.985 62	9.393 57	8.852 68
2	1.886 09	1.859 41	1.833 39	14	10.563 07	9.898 64	9.294 98
3	2.775 1	2.723 25	2.673 01	15	11.118 43	10.379 66	9.712 25
4	3.629 9	3.545 95	3.465 1	16	11.651 28	10.837 78	10.105 89
5	4.452 03	4.329 48	4.212 36	17	12.166 26	11.274 07	10.477 26
6	5.242 15	5.075 69	4.917 32	18	12.659 26	11.689 58	10.827 6
7	6.002 03	5.786 37	5.582 38	19	13.133 88	12.085 32	11.158 11
8	6.731 76	6.463 21	6.209 79	20	13.590 29	12.462 21	11.469 92
9	7.436 4	7.107 82	6.801 69	21	14.029 12	12.821 15	11.764 07
10	8.110 85	7.721 73	7.360 08	22	14.451 12	13.163	12.041 58
11	8.760 44	8.306 41	7.886 87	23	14.856 82	13.488 07	12.303 38
12	9.385 05	8.863 25	8.383 84	24	15.246 95	13.798 64	12.550 35

For a Rate of Interest and Term of Years not given in either Table.

$$\frac{P}{r}\left[1 - \frac{1}{(1+r)^n}\right] = A. \quad \textit{Notation as preceding.}$$

ILLUSTRATION.—Take $1 at 4 per cent. for 24 years.

Log. 1.04 = .017 033, which × 24 = .408 799. log. .408 799 = 2.5633 = *ratio raised to power of* 24.

$$\text{Then, } \frac{1}{.04} \times \left(1 - \frac{1}{2.5633}\right) = 25 \times \overline{1 - .390\,122} = \$15.24.695.$$

T.. Compute Yearly Amount that will Liquidate a Debt .. Given Number of Years at Compound Interest.

..STRATION.—What is amount of an annual payment that

.. in 6 years at 5 per cent. compound interest?

$\left.05\right)^6$ per table, page 108, $\dfrac{100 \times .05\,(1+.05)^6}{(1+.05)^6-1} = \dfrac{5 \times 1.34}{1.34-1} = \dfrac{6.7}{.34} = \$19.76.$

Annuities do not commence till a certain period of time, they are said to be *sion.*

mpute Present Worth of an Annuity in Reversion.

—Take two amounts under rate in above table—viz., that opposite sum of en times and that of time of reversion; multiply their difference by an- nd product will give present worth.

PLE.—What is present worth of the reversion of a lease of \$40 per annum, nue for 6 years, but not to commence until end of 2 years, at rate of 6 per

6 + 2 = 8 years 6.209 79
2 " 1.833 39
4.370 40 × 40 = \$175.05.6.

unt of Annuity of \$1, etc., Compound Interest, from 1 to 20 Years.

4 Cent.	5 Per Cent.	6 Per Cent.	7 Per Cent.	Years.	4 Per Cent.	5 Per Cent.	6 Per Cent.	7 Per Cent.
	1.	1.	1.	11	13.486 35	14.206 79	14.971 64	15.783 6
04	2.05	2.06	2.07	12	15.025 8	15.917 13	16.869 94	17.888 45
121 6	3.152 5	3.183 6	3.214 9	13	16.626 84	17.712 98	18.882 14	20.140 64
246 46	4.310 12	4.374 62	4.439 94	14	18.291 91	19.598 63	21.015 07	22.550 49
416 32	5.525 63	5.637 09	5.750 74	15	20.023 59	21.578 56	23.275 97	25.129 02
532 97	6.801 91	6.975 32	7.153 29	16	21.824 53	23.657 49	25.672 53	27.888 05
898 29	8.142 01	8.393 84	8.654 02	17	23.697 51	25.840 37	28.212 88	30.840 22
214 23	9.549 11	9.897 47	10.259 8	18	25.645 41	28.132 38	30.905 65	33.999 03
582 79	11.026 56	11.491 32	11.977 99	19	27.671 23	30.539	33.759 99	37.378 96
006 11	12.577 89	13.180 79	13.816 45	20	29.778 08	33.065 95	36.785 59	40.995 49

TRATION.—What is amount of \$1000 for 20 years at 5 per cent.?

er cent. for 20 years = 33.065 95; hence, 1000 × 33.065 95 = \$33.06.595.

ompute Amount of an Annuity for any Period and Rate.

.—From table for Compound Interest, page 108, take value for rate per cent. ar, and raise it to a power determined by time in years, from which subtract e remainder by rate, and quotient multiplied by annuity will give amount l.

PLE.—What will an annuity of \$50, payable yearly, amount to in 4 years, at nt.?

ble, page 108, $1.05^4 = 1.2155$.

$1.2155 - 1 \div (1.05 - 1) = 4.31$, and $4.31 \times 50 = \$215.50$.

For Half-yearly and Quarterly Payments.

ly annuity for given time by amount in following table:

mt.	Half-yearly.	Quarterly.	Rate per cent.	Half-yearly.	Quarterly.
	1.007 445	1.011 181	5.5	1.013 567	1.020 395
	1.008 675	1.013 031	6	1.014 781	1.022 227
	1.009 902	1.014 877	6.5	1.015 993	1.024 055
	1.011 126	1.016 729	7	1.017 204	1.025 88
	1.012 348	1.018 559	7.5	1.018 414	1.027 704

LATION 1.—Annuity as determined in previous case = \$215.50.

215.50 × 1.012 348 from above table = \$218.16 *for half yearly payments.*

rson 30 years of age has an annuity for 10 years, present wor ovided he may live for 10 years. What is annuity worth, s out of every *3550*, between the ages of 30 and 40, die annu

3550 — 600 (60 × 10) = 2950 would therefore be living.
And, 3550 : 2950 :: 1000 = \$830.98.

PERPETUITIES.

PERPETUITIES are such Annuities as continue forever.

To Compute Value of a Perpetual Annuity.

RULE.—Divide annuity by rate per cent., and multiply quotient by unit in preceding table.

EXAMPLE.—What is present worth of an annuity for \$100, payable semi-annually, at 5 per cent.?

$100 \div .05 = 2$, and $2 \times 1.012\,348$, from preceding table $= 2.024.70$.

To Compute Value of a Perpetuity in Reversion.

RULE.—Subtract present worth of annuity for time of reversion from worth of annuity, to commence immediately.

EXAMPLE.—What is present worth of an estate of \$50 per annum, at 5 per cent., to commence in 4 years?

$50 \div .05$ .... $= 1000$
\$50, for 4 years, at 5 per cent. $= 3.545\,95$ (from table, page 110) $\times 50 =$ 177.2975
822.7025

which in 4 years, at 5 per cent. compound interest, would produce \$1000.

COMBINATION.

COMBINATION is a rule for ascertaining how often a less number of numbers or things can be chosen varied from a greater, or how many different collections may be formed without regard to order of each collection.

Combinations of any number of things signify the different collections which may be formed of their quantities, without regard to the *order* of their arrangement.

Thus, 3 letters, *a*, *b*, *c*, taken *all together*, form but one combination, *abc*. Taken *two* and *two*, they form 3 combinations, as *ab*, *ac*, *bc*.

NOTE.—Class of the combination is determined by number of elements or things to be taken; if two are taken, the combination is of 2d class, and so on.

RULE.—Multiply together natural series 1, 2, 3, etc., up to the number to be taken at a time. Take a series of as many terms, decreasing by 1, from number out of which combination is to be made, ascertain their continued product, and divide this last product by former.

EXAMPLE 1.—How many single combinations, as *ab*, *ac*, may be made of 2 letters out of 3?

$$\frac{1 \times 2}{3 \times 2} = \frac{2}{6} = \frac{6}{2} = 3.$$

2.—How many combinations may be made of 7 letters out of 12?

$$\frac{1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7}{12 \times 11 \times 10 \times 9 \times 8 \times 7 \times 6} = \frac{5040}{3\,991\,680}, \text{ and } \frac{3\,991\,680}{5040} = 792.$$

3.—How many different hands of cards may be held, as at whist, combinations 13 out of 52? 635 013 559 600.

When two Numbers or Things are Combined.

RULE.—Multiply together natural series 1, 2, 3, etc., to one less term than number of combinations; ascertain their continued product, and proceed as before.

EXAMPLE.—There are 3 cards in a box, out of which two are to be drawn in a required order. How many combinations are there?

Here there are 2 terms; hence, $2 - 1 = 1$, and $\frac{1}{3 \times 2} = \frac{1}{6} = 6 \div 1 = 6$.

To Compute Number of Ways in which any Number of ...nct Objects can be Divided among any Number.

...ltiply together numbers equal to number given, as often as objects ...ied among them.

...fferent ways can 10 different cards be divided among ... $\times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3 \times 3$ or $3^{10} = 59049$.

Combinations with Repetitions.

is case the repetition of a term is considered a new combination. Thus, nits of but one combination, if not repeated; if repeated, however, it admits combinations, as 1, 1; 1, 2; 2, 2.

.—To number of terms of series add number of class of combination, less 1; y sum by successive decreasing terms of series, down to last term of series; vide this product by number of permutations of the terms, denoted by class bination.

PLE.—How many different combinations of numbers of 6 figures can be ut of 11?

$(6-1)=16=$ *sum of number of terms, and number of class, less* 1.
$15\times14\times13\times12\times11=5\,765\,760=$ *product of sum, and successive terms to* n.
$\times3\times4\times5\times6=720$ *permutations of class of combination.*

$$\text{Then, } \frac{5\,765\,760}{720}=8008.$$

Variations with Repetitions.

y different arrangement of individual number or things, including repeti- s termed a Variation.
of Variation is denoted by number of individual things taken at a time.

.—Raise number denoting the individual things to a power, the exponent h is number expressing class of variation.

PLE 1.—How many variations with 4 repetitions can be made out of 5 fig-

$$5^4=625.$$

low many different combinations of 4 places of figures can be made out of gits?

$$9+(4-1)=12, \text{ and } \frac{12\times11\times10\times9}{1\times2\times3\times4}=\frac{11\,880}{24}=495.$$

Combination without Repetitions.

—From number of terms of series subtract number of class of combination, multiply this remainder by successive increasing terms of series, up to last f series; then divide this product by number of permutations of the terms, l by class of combination.

IPLE 1.—How many combinations can be made of 4 letters out of 10, exclud- r repetition of them in any second combination?

$(4-1)=7=$ *number of terms — number of class, less* 1.
$\times9\times10=5040=$ *prod. of remainder* 7, *and successive terms up to last term.*
$\times3\times4=24=$ *permutations of class of combination.*

$$\text{Then, } \frac{5040}{24}=210.$$

low many combinations of the 5th class, without repetitions, can be made ifferent articles?

$$12-(5-1)=8, \text{ and } \frac{8\times9\times10\times11\times12}{1\times2\times3\times4\times5}=\frac{85\,040}{120}=792.$$

CIRCULAR MEASURE.

of Circular Measure is an angle which is subtended at rc equal to radius of that circle, being equal to

$$\frac{180^\circ}{3.1416}=57.296^\circ.$$

ar measure of an angle is equal to a fraction which has *btended by that angle at* centre of any circle, and for it *that circle.*

K*

Wrought Iron, Steel, Copper, and Brass Wi

American Gauge. f. full, l. light.

No. of Gauge.	Diameter.	Iron.	Steel.	Copper.	Br
		Per Lineal Foot.			
	Inch.	Lbs.	Lbs.	Lbs.	L
0000	.46 or $\frac{7}{16}$ f.	.560 74	.566 03	.640 513	.605
000	.409 64	.444 683	.448 879	.507 946	.479
00	.364 8 or $\frac{3}{8}$ l.	.352 659	.355 986	.402 83	.380
0	.324 86 or $\frac{5}{16}$ f.	.279 665	.282 303	.319 451	.301
1	.289 3	.221 789	.223 891	.253 342	.239
2	.257 63 or $\frac{1}{4}$ f.	.175 888	.177 548	.200 911	.189
3	.229 42	.139 48	.140 796	.159 323	.150
4	.204 31 or $\frac{1}{5}$ f.	.110 616	.111 66	.126 353	.119
5	.181 94 or $\frac{3}{16}$ l.	.087 72	.088 548	.100 2	.094
6	.162 02	.069 565	.070 221	.079 462	.075
7	.144 28	.055 165	.055 685	.063 013	.059
8	.128 49 or $\frac{1}{8}$ f.	.043 751	.044 164	.049 976	.047
9	.114 43	.034 699	.035 026	.039 636	.037
10	.101 89 or $\frac{1}{10}$ f.	.027 512	.027 772	.031 426	.029
11	.090 742	.021 82	.022 026	.024 924	.023
12	.080 808	.017 304	.017 468	.019 766	.018
13	.071 961	.013 722	.013 851	.015 674	.014
14	.064 084	.010 886	.010 989	.012 435	.011
15	.057 068	.008 631	.008 712	.009 859	.009
16	.050 82 or $\frac{1}{20}$ f.	.006 845	.006 909	.007 819	.007
17	.045 257	.005 427	.005 478	.006 199	.005
18	.040 303	.004 304	.004 344	.004 916	.004
19	.035 89	.003 413	.003 445	.003 899	.003
20	.031 961	.002 708	.002 734	.003 094	.002
21	.028 462	.002 147	.002 167	.002 452	.002
22	.025 347	.001 703	.001 719	.001 945	.001
23	.022 571	.001 35	.001 363	.001 542	.001
24	.020 1 or $\frac{1}{50}$ f.	.001 071	.001 081	.001 223	.001
25	.017 9	.000 849 1	.000 857 1	.000 969 9	.000
26	.015 94	.000 673 4	.000 679 7	.000 769 2	.000
27	.014 195	.000 534	.000 539 1	.000 609 9	.000
28	.012 641	.000 423 5	.000 427 5	.000 483 7	.000
29	.011 257	.000 335 8	.000 338 9	.000 383 5	.000
30	.010 025 or $\frac{1}{100}$ f.	.000 266 3	.000 268 8	.000 304 2	.000
31	.008 928	.000 211 3	.000 213 2	.000 241 3	.000
32	.007 95	.000 167 5	.000 169 1	.000 191 3	.000
33	.007 08	.000 132 8	.000 134 1	.000 151 7	.000
34	.006 304	.000 105 3	.000 106 3	.000 120 4	.000
35	.005 614	.000 083 66	.000 084 45	.000 095 6	.000
36	.005 or $\frac{1}{200}$	.000 066 25	.000 066 87	.000 075 7	.000
	[illegible] 453	.000 052 55	.000 053 04	.000 060 03	.000
	[illegible] 5	.000 041 66	.000 042 05	.000 047 58	.000
		.000 033 05	.000 033 36	.000 037 75	.000
		.000 026 2	.000 026 44	.000 029 92	.000
		7.774	7.847	8.88	8.
		.87	490.45	554.988	524.
		312	.2838	.3212	.

computations of these weights were m
arpe, Providence, R. I.

ımber of cases which favor drawing of a white ball from both bags is $5 \times 7 = 35$, very one of the 5 white balls in one bag may be drawn in combination with every of the 7 in the other. For a like cause, number of cases which favor drawing of ite ball from 1st bag and a black one from 2d is $5 \times 3 = 15$; a black ball from 1st and a white ball from 2d is $7 \times 2 = 14$; and a black ball from both is $3 \times 2 = 6$. obability, therefore, of drawing is as

$\frac{\times 7}{0} = \frac{35}{70} = \frac{1}{2} = 1$ to 1, *a white ball from both bags.* $\frac{5 \times 3}{70} = \frac{15}{70} = \frac{3}{14} = 3$ to 11, *ite ball from 1st, and a black from 2d.* $\frac{7 \times 2}{70} = \frac{14}{70} = \frac{1}{5} = 1$ to 4, *a black from 1st, and a white from 2d.* $\frac{3 \times 2}{70} = \frac{6}{70} = \frac{3}{35} = 3$ to 32, *a black ball from*

$\frac{5 \times 3 + 2 \times 7}{70} = \frac{29}{70} = 29$ to 41, *a white ball from one, and a black from other,* oth 2d and 3d cases favor this result; hence, $\frac{1}{5} + \frac{3}{14} = \frac{29}{70}$. $\frac{5 \times 7 + 5 \times 3 + 2 \times 7}{70}$ $= \frac{32}{35} = 32$ to 3, *at least one white ball,* for the 1st, 2d, and 3d cases favor this ; hence, $\frac{1}{2} + \frac{3}{14} + \frac{1}{5} = \frac{32}{35}$.

ıin, if number of white and black balls in each bag are same, say 5 white and k, $\overline{5+2} \times \overline{5+2} = 49$, then probability of drawing is as

$\frac{5}{} = \frac{25}{49} = 25$ to 24, *a white ball from both.* $\frac{5 \times 2}{49} = \frac{10}{49} = 10$ to 39, *a white ball 1st, and a black from 2d.* $\frac{2 \times 5}{49} = \frac{10}{49} = 10$ to 39, *a black ball from 1st, and a from 2d.* $\frac{2 \times 2}{49} = \frac{4}{49} = 4$ to 45, *a black ball from both.*

When two dice are thrown, probability that sum of numbers on upper sides given number, say 7, is as follows:

very one of the six numbers on one die may come up alike to, or in combi- with the other, number of throws is $6 \times 6 = 36$.

ıber 7 may be a combination of $\left\{\begin{matrix} 1 \text{ and } 6 \\ 2 \quad \text{"} \quad 5 \\ 3 \quad \text{"} \quad 4 \end{matrix}\right\}$; and as these numbers may be ither die, there are $3 \times 2 = 6$ throws in favor of the combination of 7; hence ility of throwing 7 is $\frac{6}{36} = \frac{1}{6}$, or as 1 to 5.

'robability of a player's partner at Whist holding a given card is as follows: ber of cards held by the other 3 players is $3 \times 13 = 39$; probability, there- at it is held by partner is $\frac{1}{39}$, but it may be one of the 13 cards which he hence probability is $\frac{1}{39} \times 13 = \frac{13}{39} = \frac{1}{3}$, or as 1 to 2.

robability of a player's partner at Whist holding two given cards is as follow ıer of combinations of 39 things, taken 2 and 2 together, is $\frac{39 \times 38}{1 \times 2} = 7$ e, probability that these 2 cards are in partner's hand is $\frac{1}{\frac{39 \times 38}{1 \times 2}} = \frac{1}{39 \times}$ 1 to 740; but they may be any 2 cards in partner's hand; therefore, since of combinations of 13 cards, taken 2 and 2 together, is $\frac{13 \times 12}{1 \times 2} = \frac{156}{}$ ity required is $\frac{78}{741} = \frac{2}{19}$, or as 2 to 17.

rly, probability that he holds any 3 given cards is as $\frac{22}{703}$, or

WEIGHT AND STRENGTH OF WIRE, IRON, ETC.

Weight and Strength of Warrington Iron Wire.

Manufactured by Rylands Brothers. (England.)

Weight per 100 *Lineal Feet.*

No.	Diameter.	Weight.	Breaking Weight. Annealed.	Breaking Weight. Bright.	No.	Diameter.	Weight.	Breaking Weight. Annealed.	Breaking Weight. Bright.
Gauge.	Inch	Lbs.	Lbs.	Lbs.	Gauge.	Inch.	Lbs.	Lbs.	Lbs.
7/0	1/2	64.46	3490	5233	9	.146	5.5	298	447
6/0	15/32	56.66	3066	4603	10	.133	4.43	247	370
5/0	7/16	49.36	2673	4000	10.5	.125	4.03	218	327
4/0	13/32	42.53	2303	3457	11	.117	3.53	191	288
3/0	3/8	36.26	1963	2945	12	.1	2.66	145	217
2/0	11/32	30.46	1653	2473	13	.09	2.1	113	169
0	.326	27.36	1486	2226	14	.079	1.6	87	130
1	.3	23.3	1257	1885	15	.069	1.23	66	99
2	.274	19.36	1046	1572	16	.0625	.96	53	77
3	.25	16.13	873	1309	17	.053	.73	39	59
4	.229	13.53	732	1098	18	.047	.56	31	46
5	.209	11.26	610	913	19	.041	.43	23	35
6	.191	9.4	509	763	20	.036	.33	18	27
7	.174	7.8	422	633	21	.03125	.26	14	21
8	.159	6.53	353	519	22	.028	.2	11	16

To Compute Length of 100 Pounds of Wire of a Given Diameter.

Rule.—Divide following numbers by square of diameter, in parts of an inch, and quotient is length in feet.

37.68 for wrought iron.
37.45 for steel.
33.42 for copper.
34.41 for brass.
28 for silver.
15.3 for gold.
13.64 for platinum.

Window Glass.

Thickness and Weight per Square Foot.

No.	Thickness.	Weight.	No.	Thickness.	Weight.	No.	Thickness.	Weight.
	Inch.	Oz.		Inch.	Oz.		Inch.	Oz.
12	.059	12	17	.083	17	26	.125	26
13	.063	13	19	.091	19	32	.154	32
15	.071	15	21	.1	21	36	.167	36
16	.077	16	24	.111	24	42	.2	42

Terne Plates.

Terne Plates—Are of iron covered with an amalgam of lead.

Thickness and Weight of Galvanized Sheet Iron.

Sheet 2 *Feet in Width by from* 6 *to* 9 *Feet in Length* (*M. Lefferts*).

Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.
No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.
26	15	23	20	20	27	17	36	14	53		
25	16	22	22	19	30	16	42	13	61		
24	18	21	24	18	35	15	46	12	70		

Wrought Iron.

Weight of Square Rolled Iron,

From .125 *Inch to* 10 *Inches.* ONE FOOT IN LENGTH.

le.	Weight.	Side.	Weight.	Side.	Weight.	Side.	Weight.
s.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
25	.053	2.125	15.263	4.125	57.517	6.25	132.04
5	.211	.25	17.112	.25	61.055	.5	142.816
75	.475	.375	19.066	.375	64.7	.75	154.012
	.845	.5	21.12	.5	68.448	7	165.632
25	1.32	.625	23.292	.625	72 305	.25	177.672
5	1.901	.75	25.56	.75	76.264	.5	190.136
75	2.588	.875	27.939	.875	80.333	.75	203.024
	3.38	3	30.416	5	84.48	8	216.336
25	4.278	.125	33.01	.125	88.784	.25	230.068
;	5.28	.75	35.704	.25	93.168	.5	244.22
'5	6.39	.375	38.503	.375	97.657	.75	258.8
	7.604	.5	41.408	.5	102.24	9	273.792
5	8.926	.625	44.418	.625	106.953	.25	289.22
	10.352	.75	47.534	.75	111.756	.5	305.056
5	11.883	.875	50.756	.875	116.671	.75	321.33
	13.52	4	54.084	6	121.664	10	327.92

STRATION.—What is weight of a bar 1.5 inches, by 12 inches in length?
olumn 1st, find 1.5; opposite to it is 7.604 lbs., which is 7 lbs. and .604 of a lb.
er denomination of ounces is required, result is obtained as follows:

ltiply remainder by 16, point off the decimals, and the figures remain-
1 left of the point will give number of ounces.

Thus, .604 of a lb. = .604 × 16 = .9.664 = 7 *lbs.* 9.664 *ounces.*

Compute Weight for less than a Foot in Length.

ATION.—What is weight of a bar 6.25 inches square and 10.5 inches long?
olumn 7th, opposite to 6.25 is 132.04, which is weight for a foot in length.

6.25 × 12 inches = 132.04

6 ins. = .5 = 66.02
3 " = .25 = 33.01
1.5 " = .125 = 16.505

115.535 *lbs.*

Weight of Angle Iron,

From 1.25 *to* 4.5 *Inches.* ONE FOOT IN LENGTH.

Thickness measured in Middle of each Side.

EQUAL SIDES.			L UNEQUAL SIDES.			L UNEQUAL SIDES.		
s.	Thickness.	Weight	Sides.	Thickness.	Weight.	Sides.	Thickness.	Weight.
.	Inch.	Lbs.	Ins.	Inch.	Lbs.	Ins.	Inch.	Lbs.
1.25	.1875	1.5	3 × 2.5	.375	6.25	6 × 3.5	.625	18
1.5	.1875	2	3.5 × 3	.4375	7.75	6 × 4.5	.625	20
1.75	.25	3	3.5 × 3	.4375	9.6			
2	.25	3.5	4 × 3	.5	11	T		
2.25	.3125	4.5	4 × 3.5	.5	11.5	2 × 2.375*	.375	5.5
2.5	.3125	5	4 × 3.5	.5	11.75	2.5 × 2.875	.375	6.5
3	.375	7	4.5 × 3	.5	11.75	3.5 × 3.5	.4375	10.5
3.5	.4375	9	5 × 3	.5	12.65	4 × 3.5	.4375 .75	12
4	.5	12.5	5 × 3	.5625	13.7			
4.5	.5	14	5.5 × 3.5	.5	14.5	4 × 3.5		
4.5	.5625	16	5.5 × 3.5	.5625	15.6			

* *This column gives depth of web added to the thickness of base or fl*

WEIGHTS OF IRON, STEEL, COPPER, ETC.

Wrought Iron, Steel, Copper, and Brass

SOFT ROLLED. (*American Gauge.*)

No. of Gauge.	Thickness.	Iron.	Steel.	Copper.
		Per Square Foot.		
	Inch.	Lbs.	Lbs.	Lbs.
0000	.46 or 7/16 full	18.4575	18.7036	20.838
000	.409 64	16.4368	16.6559	18.556 7
00	.364 8 or 3/8 light	14.6376	14.8328	16.525 4
0	.324 86 or 1/3 "	13.0351	13.2088	14.716 2
1	.289 3	11.6082	11.7629	13.105 3
2	.257 63 or 1/4 full	10.3374	10.4752	11.670 6
3	.229 42	9.2055	9.3283	10.392 7
4	.204 31 or 1/5 full	8.1979	8.3073	9.255 2
5	.181 94 or 3/16 light	7.3004	7.3977	8.241 9
6	.162 02	6.5011	6.5878	7.339 5
7	.144 28	5.7892	5.8664	6.535 9
8	.128 49 or 1/8 full	5.1557	5.2244	5.820 6
9	.114 43	4.5915	4.6527	5.183 7
10	.101 89 or 1/10 full	4.0884	4.1428	4.615 6
11	.090 742	3.641	3.6896	4.110 6
12	.080 808	3.2424	3.2856	3.660 6
13	.071 961	2.8874	2.9259	3.259 8
14	.064 084	2.5714	2.6057	2.903
15	.057 068	2.2899	2.3204	2.585 2
16	.050 82 or 1/20 full	2.0392	2.0664	2.302 1
17	.045 257	1.8159	1.8402	2.050 1
18	.040 303	1.6172	1.6387	1.825 7
19	.035 89	1.44	1.4593	1.625 8
20	.031 961	1.2824	1.2995	1.447 8
21	.028 462	1.142	1.1573	1.289 3
22	.025 347	1.017	1.0306	1.148 2
23	.022 571	.9057	.9177	1.022 5
24	.021 1	.8065	.8173	.910 53
25	.017 9	.7182	.7278	.810 87
26	.015 94	.6396	.6481	.722 08
27	.014 195	.5696	.5772	.643 03
28	.012 641	.5072	.514	.572 64
29	.011 257	.4517	.4577	.509 94
30	.010 025	.4023	.4076	.454 13
31	.008 928	.3582	.363	.404 44
32	.007 95	.319	.3232	.360 14
33	.007 08	.2841	.2879	.320 72
34	.006 304	.2529	.2563	.285 57
35	.005 614	.2253	.2283	.254 31
36	.005	.2006	.2033	.226 5
37	.004 453	.1787	.181	.201 72
38	.003 965	.1591	.1612	.179 61
39	.003 531	.1417	.1436	.159 95
40	.003 144	.1261	.1278	.142 42
Specific Gravities		7.704	7.806	8.698
Weights of a Cube Foot		481.75	487.75	543.6
" " Inch		.278 7	.2823	.314 6

Wrought Iron, Steel, Copper, and Brass Plates.

(Birmingham Gauge.)

No. of Gauge.	Thickness.	Per Square Foot. Iron.	Steel.	Copper.	Brass.
	Inch.	Lbs.	Lbs.	Lbs.	Lbs.
0000	.454 or $\frac{7}{16}$ full	18.2167	18.4596	20.5662	19.4312
000	.425	17.0531	17.2805	19.2525	18.19
00	.38 or $\frac{3}{8}$ full	15.2475	15.4508	17.214	16.264
0	.34 or $\frac{1}{3}$ "	13.6425	13.8244	15.402	14.552
1	.3	12.0375	12.198	13.59	12.84
2	.284	11.3955	11.5474	12.8652	12.1552
3	.259 or $\frac{1}{4}$ full	10.3924	10.5309	11.7327	11.0852
4	.238	9.5497	9.6771	10.7814	10.1864
5	.22	8.8275	8.9452	9.966	9.416
6	.203 or $\frac{1}{5}$ full	8.1454	8.254	9.1959	8.6884
7	.18 or $\frac{3}{16}$ light	7.2225	7.3188	8.154	7.704
8	.165 or $\frac{1}{6}$ "	6.6206	6.7089	7.4745	7.062
9	.148 or $\frac{1}{7}$ full	5.9385	6.0177	6.7044	6.3344
10	.134	5.3767	5.4484	6.0702	5.7352
11	.12 or $\frac{1}{8}$ light	4.815	4.8792	5.436	5.136
12	.109	4.3736	4.4319	4.9377	4.6652
13	.095 or $\frac{1}{10}$ light	3.8119	3.8627	4.3035	4.066
14	.083	3.3304	3.3748	3.7599	3.5524
15	.072	2.889	2.9275	3.2616	3.0816
16	.065	2.6081	2.6429	2.9445	2.782
17	.058	2.3272	2.3583	2.6274	2.4824
18	.049 or $\frac{1}{20}$ light	1.9661	1.9923	2.2197	2.0972
19	.042	1.6852	1.7077	1.9026	1.7976
20	.035	1.4044	1.4231	1.5855	1.498
21	.032	1.284	1.3011	1.4496	1.3696
22	.028	1.1235	1.1385	1.2684	1.1984
23	.025 or $\frac{1}{40}$	1.0031	1.0165	1.1325	1.07
24	.022	.8827	.8945	.9966	.9416
25	.02 or $\frac{1}{50}$	.8025	.8132	.906	.856
26	.018	.7222	.7319	.8154	.7704
27	.016	.642	.6506	.7248	.6848
28	.014	.5617	.5692	.6342	.5992
29	.013	.5216	.5286	.5889	.5564
30	.012	.4815	.4879	.5436	.5136
31	.01 or $\frac{1}{100}$	.4012	.4066	.453	.428
32	.009	.3611	.3659	.4077	.3852
33	.008	.321	.3253	.3624	.3424
34	.007	.2809	.2846	.3171	.2996
35	.005 or $\frac{1}{200}$	.2006	.2033	.2265	.214
36	.004 or $\frac{1}{250}$	.1605	.1626	.1812	.1712

Thickness of Sheet Silver, Gold, etc.

By Birmingham Gauge for these Metals.

No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
1	.004	7	.015	13	.036	19	.064	25	.095	31	.133
2	.005	8	.016	14	.041	20	.067	26	.103	32	.143
3	.008	9	.019	15	.047	21	.072	27	.113	33	.145
4	.01	10	.024	16	.051	22	.074	28	.12	34	.148
5	.013	11	.029	17	.057	23	.077	29	.124	35	.158
6	.013	12	.034	18	.061	24	.082	30	.126	36	

Thickness. Ins.	Weight. Lbs.
	3.25
1.375	15.102
1.5	16.475
1.625	17.848
1.75	19.221
1.875	20.594
2	21.967
2.25	24.712
2.5	27.458
2.75	30.204
3	32.95
	3.5
.125	1.479
.25	2.957
.375	4.436
.5	5.914
.625	7.393
.75	8.871
.875	10.35
1	11.828
1.125	13.307
1.25	14.785
1.375	16.264
1.5	17.742
1.625	19.221
1.75	20.699
1.875	22.178
2	23.656
2.25	26.613
2.5	29.57
2.75	32.527
3	35.485
3.25	38.441
	3.75
.125	1.584
.25	3.168
.375	4.752
.5	6.336
.625	7.921
.75	9.505
.875	11.089
1	12.673
1.125	14.257
1.25	15.841
1.375	17.425
1.5	19.009
1.625	20.594
1.75	22.178

Thickness. Ins.	Weight. Lbs.
	3.75
1.875	23.762
2	25.346
2.25	28.514
2.5	31.682
2.75	34.851
3	38.019
3.25	41.187
3.5	44.355
	4
.125	1.69
.25	3.38
.5	6.759
.75	10.138
1	13.518
1.25	16.897
1.5	20.277
1.75	23.656
2	27.036
2.25	30.415
2.5	33.795
2.75	37.174
3	40.554
3.25	43.933
3.5	47.313
3.75	50.692
	4.25
.125	1.795
.25	3.591
.5	7.181
.75	10.772
1	14.364
1.25	17.953
1.5	21.544
1.75	25.135
2	28.725
2.25	32.316
2.5	35.907
2.75	39.497
3	43.088
3.25	46.679
3.5	50.269
3.75	53.86
4	57.45
	4.5
.25	3.802
.5	7.604

Thickness. Ins.	Weight. Lbs.
	4.5
.75	11.406
1	15.208
1.25	19.01
1.5	22.812
1.75	26.614
2	30.415
2.25	34.217
2.5	38.019
2.75	41.82
3	45.623
3.25	49.425
3.5	53.226
3.75	57.028
4	60.83
4.25	64.632
	4.75
.25	4.013
.5	8.026
.75	12.036
1	16.052
1.25	20.066
1.5	24.079
1.75	28.092
2	32.105
2.25	36.118
2.5	40.131
2.75	44.144
3	48.157
3.25	52.17
3.5	56.184
3.75	60.197
4	64.21
4.25	68.223
4.5	72.235
	5
.25	4.224
.5	8.449
.75	12.673
1	16.897
1.25	21.122
1.5	25.346
1.75	29.57
2	33.795
2.25	38.019
2.5	42.243
2.75	46.468
3	50.692

Thickness. Ins.	Weight. Lbs.
	5
3.25	54.916
3.5	59.14
3.75	63.365
4	67.589
4.25	71.813
4.5	76.038
4.75	80.262
	5.25
.25	4.436
.5	8.871
.75	13.307
1	17.742
1.25	22.178
1.5	26.613
1.75	31.049
2	35.484
2.25	39.92
2.5	44.355
2.75	48.791
3	53.226
3.25	57.662
3.5	62.097
3.75	66.533
4	70.968
4.25	75.404
4.5	79.839
4.75	84.275
5	88.71
	5.5
.25	4.647
.5	9.294
.75	13.94
1	18.587
1.25	23.234
1.5	27.881
1.75	32.527
2	37.174
2.25	41.821
2.5	46.468
2.75	51.114
3	55.761
3.25	60.408
3.5	65.055
3.75	69.701
4	74.348
4.25	78.995
4.5	83.642

ILLUSTRATION.—**What is weight of a bar of iron 5.25 ins. in breadth by .75 inch in thickness**

In column 7, as above, **find 5.25; and below it, in column, .75; and opposite to** *that is 13.307, which* **is 13 lbs. and .307 of a pound.**

r parts of a pound **and of a foot, operate according to rule laid down for table,** 25.

Weight of Sheet Iron. (*English. D. K. Clark.*)

PER SQUARE FOOT (*at 480 lbs. per Cube Foot*).

As by Wire-gauge used in South Staffordshire, England.

ness.	Weight.	Square Feet in 1 ton.	Thickness.		Weight.	Square Feet in 1 ton.	Thickness.		Weight.	Square Feet in 1 ton
Inch.	Lbs.	No.	No.	Inch.	Lbs.	No.	No.	Inch.	Lbs.	No.
125	.5	4480	21	.0344	1.38	1623	10	.1406	5.63	398
141	.562	3986	20	.0375	1.5	1493	9	.1563	6.25	358
156	.625	3584	19	.0438	1.75	1280	8	.1719	6.88	326
172	.688	3256	18	.05	2	1120	7	.1875	7.5	299
188	.75	2987	17	.0563	2.25	996	6	.2031	8.13	276
203	.813	2755	16	.0625	2.5	896	5	.2188	8.75	256
219	.875	2560	15	.075	3	747	4	.2344	9.38	239
234	.938	2388	14	.0875	3.5	640	3	.25	10	224
25	1	2240	13	.1	4	560	2	.2813	11.25	199
281	1.13	1982	12	.1125	4.5	498	1	.3125	12.5	179
313	1.25	1792	11	.125	5	448				

Weight of Hoop Iron. (*English.*)

PER LINEAL FOOT.

W. G.	Weight.	Width.	W. G.	Weight.	Width.	W. G.	Weight.
No.	Lbs.	Ins.	No.	Lbs.	Ins.	No.	Lbs.
21	.067	1.125	17	.21	1.75	14	.484
20	.0875	1.25	16	.27	2	13	.634
19	.1216	1.375	15	.33	2.25	13	.714
18	.1636	1.5	15	.36	2.5	12	.91

eight of Black and Galvanized Sheet Iron.

n's Table, founded upon Sir Joseph Whitworth & Co.'s Standard Birmingham Wire-Gauge.) (*D. K. Clark.*)

—Numbers on Holtzapffel's wire-gauge are applied to thicknesses on Whit-auge.

and Weight of ck Sheets.		Approximate number of Sq. Ft. in 1 ton. Black.	Galvanized.	Gauge and Weight of Black Sheets.			Approximate number of Sq. Ft. in 1 ton Black.	Galvanized.
Inch.	Lbs.	Sq. Ft.	Sq. Ft.	No.	Inch.	Lbs.	Sq. Ft.	Sq. Ft.
3	12	187	185	17	.06	2.4	933	876
28	11.2	200	197	18	.05	2	1120	1038
26	10.4	215	212	19	.04	1.6	1400	1274
24	9.6	233	229	20	.036	1.4	1556	1403
22	8.8	254	250	21	.032	1.28	1750	1558
2	8	280	275	22	.028	1.12	2000	1753
18	7.2	311	304	23	.024	.96	2333	2004
165	6.6	339	331	24	.022	.88	2545	2159
15	6	373	363	25	.02	.8	2800	2339
135	5.4	415	403	26	.018	.72	3111	[illegible]
12	4.8	467	452	27	.016	.64	[illegible]	
11	4.4	509	491	28	.014	.56	[illegible]	
95	3.8	589	566	29	.013	.52	[illegible]	
85	3.4	659	630	30	.012	.48		
7	2.8	800	757	31	.01	.4		
65	2.6	862	813	32	.009	.36		

Weight of English Angle and T Iron. (*D. K. Cl*

ONE FOOT IN LENGTH.

NOTE.—When base or web tapers in section, mean thickness is to be measur

Thickness.	Sum of Width and Depth in Inches.									
	1.5	1.625	1.75	1.875	2	2.125	2.25	2.375	2.5	2.625	:
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	I
.125	.57	.62	.68	.73	.78	.83	.88	.94	.99	1.04	
.1875	.81	.89	.97	1.05	1.13	1.21	1.29	1.37	1.45	1.52	
.25	1.04	1.15	1.25	1.36	1.46	1.56	1.67	1.77	1.88	1.98	
.3125	1.24	1.37	1.5	1.63	1.76	1.89	2.02	2.15	2.28	2.41	
	2.875	3	3.125	3.25	3.375	3.5	3.625	3.75	3.875	4	
.125	1.14	1.2	1.25	1.3	1.45	1.41	1.46	1.51	1.56	1.62	
.1875	1.68	1.76	1.84	1.91	1.99	2.07	2.15	2.23	2.3	2.38	
.25	2.19	2.29	2.4	2.5	2.6	2.71	2.81	2.92	3.02	3.13	
.3125	2.67	2.8	2.93	3.06	3.19	3.32	3.45	3.58	3.71	3.84	
.375	3.13	3.28	3.44	3.59	3.75	3.91	4.06	4.22	4.38	4.53	
.4375	3.57	3.75	3.93	4.11	4.29	4.48	4.66	4.84	5.02	5.2	
	4.5	4.75	5	5.25	5.5	5.75	6	6.25	6.5	6.75	
.1875	2.7	2.85	3.01	3.16	3.32	3.48	3.63	3.79	3.95	4.1	
.25	3.54	3.75	3.96	4.17	4.38	4.[illegible]	4.79	5	5.21	5.42	
.3125	4.36	4.62	4.88	5.14	5.4	5.66	5.92	6.18	6.45	6.71	
.375	5.16	5.47	5.78	6.09	6.41	6.72	7.03	7.34	7.66	7.97	
.4375	5.92	6.29	6.65	7.02	7.38	7.75	8.11	8.48	8.84	9.21	
.5	6.67	7.08	7.5	7.92	8.33	8.75	9.17	9.58	10	10.42	I
.5625	7.38	7.85	8.32	8.79	9.26	9.73	10.2	10.66	11.13	12.6	I
	7.25	7.5	7.75	8	8.25	8.5	8.75	9	9.25	9.5	
.25	5.83	6.04	6.25	6.46	6.67	6.88	7.08	7.29	7.5	7.71	
.3125	7.23	7.49	7.75	8.01	8.27	8.53	8.79	9.05	9.31	9.57	
.375	8.59	8.91	9.22	9.53	9.84	10.16	10.47	10.78	11.09	11.41	I
.4375	9.93	10.3	10.66	11.03	11.39	11.76	12.12	12.49	12.85	13.22	I
.5	11.25	11.67	12.08	12.5	12.92	13.33	13.75	14.17	14.58	15	I
.5625	12.54	13.01	13.48	13.94	14.41	14.88	15.35	15.82	16.29	16.76	1
.625	13.8	14.32	14.84	15.36	15.89	16.41	16.93	17.45	17.97	18.49	I
	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	
.375	12.03	12.66	13.28	13.91	14.53						
.4375	13.95	14.67	15.4	16.13	16.86	17.59	18.31	19.04	19.77	20.5	2
.5	15.83	16.67	17.5	18.33	19.17	20	20.84	21.67	22.5	23.34	2
.5625	17.7	18.63	19.57	20.51	21.44	22.38	23.31	24.25	25.19	26.12	2
.625	19.53	20.57	21.61	22.66	23.7	24.74	25.78	26.83	27.87	28.91	2
.75	23.13	24.38	25.63	26.88	28.13	29.37	30.63	31.88	33.13	34.38	3
	12	12.5	13	13.5	14	15	16	17	18	19	
.625	23.7	24.74	25.78	26.83	27.87	29.95	32.03	34.12	36.2	38.28	4
--	28.13	29.37	30.63	31.88	33.13	35.63	38.13	40.63	41.13	43.63	4
	.45	33.91	35.36	36.82	38.28	41.19	44.12	47.02	49.95	52.87	5
	67	38.33	40	41.67	43.33	46.67	50	53.33	56.67	60	6

merican rolled is slightly heavier.

Weight of Hoop Iron. (*D. K. Clark.*)

ONE FOOT IN LENGTH.

As by Wire-gauge used in South Staffordshire (England).

ness.	Width in Inches.										
	.625	.75	.875	1	1.125	1.25	1.375	1.5	1.625	1.75	2
ich.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
344	.0716	.0861	.1	.115	.129	.144	.158	.172	.197	.201	.229
375	.0781	.0938	.109	.125	.141	.156	.172	.188	.203	.219	.25
438	.0911	.109	.128	.146	.164	.182	.2	.219	.238	.257	.292
5	.104	.125	.146	.167	.188	.208	.229	.25	.271	.292	.333
563	.117	.141	.164	.188	.211	.234	.258	.281	.305	.328	.375
625	.13	.156	.182	.208	.234	.26	.286	.313	.339	.365	.417
75	.156	.188	.219	.25	.281	.313	.344	.375	.307	.438	.5
875	.183	.219	.256	.293	.329	.366	.402	.438	.475	.512	.585
	.208	.25	.292	.333	.375	.416	.458	.5	.543	.584	.667
125	.234	.281	.328	.375	.422	.469	.516	.563	.609	.656	.75
25	.26	.313	.365	.417	.469	.521	.573	.625	.677	.729	.833
406	.293	.352	.41	.469	.527	.586	.645	.703	.762	.82	.938
563	.326	.391	.456	.522	.587	.652	.717	.783	.848	.913	1.04
719	.358	.43	.501	.573	.644	.716	.788	.859	.931	1	1.15
875	.391	.469	.547	.625	.703	.781	.859	.938	1.02	1.09	1.25
031	.423	.508	.593	.677	.762	.836	.931	1.02	1.1	1.19	1.35
188	.456	.547	.638	.729	.82	.912	1	1.09	1.19	1.28	1.46
344	.488	.586	.683	.781	.879	.977	1.07	1.17	1.27	1.37	1.56

CAST IRON.

Compute Weight of a Cast Iron Bar or Rod.

ertain weight of a wrought iron bar or rod of same dimensions in ing tables, or by computation, and from weight deduct $\frac{2}{27}$th part.

As .1000 : .9257 :: weight of a wrought bar or rod : to weight re- . Thus, what is weight of a piece of cast iron 4 × 3.75 × 12 inches? ible, page 128, weight of a piece of wrought iron of these dimensions 92 lbs. Then, 1000 : .9257 :: 50.692 : 46.93 *lbs.*

Braziers' and Sheathing Copper.

ERS' SHEETS, 2 × 4 feet from 5 to 25 lbs., 2.5 × 5 feet from 9 to 150 lbs., and et and 4 × 6 feet, from 16 to 300 lbs. per sheet.

HING COPPER, 14 × 48 inches, and from 14 to 34 oz. per square foot.

W METAL, 14 × 48 inches, and from 16 to 34 oz. per square foot.

Weight of Corrugated Iron Roof Plates.

PER SQUARE FOOT. (*Birmingham Gauge.*)

Black.	Galvanized.	No.	Black.	Galvanized.	No.	Black.	Galvanized.
Oz.	Oz.		Oz.	Oz.		Oz.	Oz.
26	29	23	20	22	25	16	18
22	24	24	18	20	26	14	16

METALS.

Compute Weight of Metals of any I sions or Form.

les in Mensuration of Solids (page 360), ascertain v ultiply *it by weight of* a cube inch, and product wi a.

WEIGHT AND STRENGTH OF WIRE, IRON, ETC.

Weight and Strength of Warrington Iron Wire.

Manufactured by Rylands Brothers. (England.)

Weight per 100 *Lineal Feet.*

No.	Diameter.	Weight	Breaking Weight. An-nealed.	Breaking Weight. Bright.	No.	Diameter.	Weight.	Breaking Weight. An-nealed.	Breaking Weight. Bright.
Gauge.	Inch	Lbs.	Lbs.	Lbs.	Gauge.	Inch.	Lbs.	Lbs.	Lbs.
7/0	1/2	64.46	3490	5233	9	.146	5.5	298	447
6/0	15/32	56.66	3066	4603	10	.133	4.43	247	370
5/0	7/16	49.36	2673	4000	10.5	.125	4.03	218	327
4/0	13/32	42.53	2303	3457	11	.117	3.53	191	288
3/0	3/8	36.26	1963	2945	12	.1	2.66	145	217
2/0	11/32	30.46	1653	2473	13	.09	2.1	113	169
0	.326	27.36	1486	2226	14	.079	1.6	87	130
1	.3	23.3	1257	1885	15	.069	1.23	66	99
2	.274	19.36	1046	1572	16	.0625	.96	53	77
3	.25	16.13	873	1309	17	.053	.73	39	59
4	.229	13.53	732	1098	18	.047	.56	31	46
5	.209	11.26	610	913	19	.041	.43	23	35
6	.191	9.4	509	763	20	.036	.33	18	27
7	.174	7.8	422	633	21	.03125	.26	14	21
8	.159	6.53	353	519	22	.028	.2	11	16

To Compute Length of 100 Pounds of Wire of a Given Diameter.

RULE.—Divide following numbers by square of diameter, in parts of an inch, and quotient is length in feet.

37.68 for wrought iron.
37.45 for steel.
33.42 for copper.
34.41 for brass.
28 for silver.
15.3 for gold.
13.64 for platinum.

WINDOW GLASS.

Thickness and Weight per Square Foot.

No.	Thickness.	Weight.	No.	Thickness.	Weight.	No.	Thickness.	Weight.
	Inch.	Oz.		Inch.	Oz.		Inch.	Oz.
12	.059	12	17	.083	17	26	.125	26
13	.063	13	19	.091	19	32	.154	32
15	.071	15	21	.1	21	36	.167	36
16	.077	16	24	.111	24	42	.2	42

Terne Plates.

Terne Plates—Are of iron covered with an amalgam of lead.

Thickness and Weight of Galvanized Sheet Iron.

Sheet 2 Feet in Width by from 6 to 9 Feet in Length (M. Lefferts).

Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.
No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.
29	12	26	15	23	20	20	27	17	36	14	53
8	13	25	16	22	22	19	30	16	42	13	61
	14	24	18	21	24	18	35	15	46	12	70

ter.	Thickn.	Weight.	Diameter.	Thickn.	Weight.	Diameter.	Thickn.	Weight.
.	Inch.	Lbs.	Ins	Ins.	Lbs.	Ins.	Ins.	Lbs.
'.5	.875	157.59	29	.75	218.7	40	.875	350.56
	1	181.33		.875	256.23		1	401.86
;	.625	114.1		1	294.05		1.125	453.46
	.75	137.84	30	.75	226.05		1.25	505.41
	.875	161.88		.875	264.8	42	.875	367.69
	1	186.23		1	303.86		1	421.45
)	.625	120.23		1.125	343.22		1.125	472.52
	.75	145.19	31	.75	233.41		1.25	529.87
	.875	170.46		.875	273.38	44	.875	384.88
	1	196.03		1	313.66		1	441.1
)	.625	126.35		1.125	354.24		1.125	497.58
	.75	152.54	32	.75	240.75		1.25	554.42
	.875	179.03		.875	281.95	46	.875	402.01
	1	205.84		1	323.46		1	460.07
.	.625	132.48		1.125	365.27		1.125	519.64
	.75	159.89	33	.75	248.11		1.25	578.88
	.875	187.61		.875	290.53	48	.875	419.17
	1	215.64		1	333.26		1	480.29
;	.625	138.61		1.125	376.29		1.125	541.69
	.75	167.24	34	.75	255 46		1.25	603.44
	.875	196.19		.875	299.11	50	.875	436.43
	1	225.44		1	343.06		1	499.89
;	.625	144.73		1.125	387.33		1.125	563.75
	.75	174.59	35	.75	262.81		1.25	627.93
	.875	204.76		.875	307.68	52	.875	453.49
	1	235.24		1	352.87		1	519.5
	.625	150.86		1.125	398.35		1.125	585.81
	.75	181.95	36	.75	270.16		1.25	654.42
	.875	213.34		.875	316.26	55	.875	479.23
	1	245.04		1	362.67		1	548.9
	.625	156.98		1.125	409.28		1.125	618.91
	.75	189.3		1.25	456.37		1.25	689.21
	.875	221.92	37	.75	277.51	58	1	578.29
	1	254.85		.875	324.84		1.125	651.96
	.625	163.11		1	372.47		1.25	725.93
	.75	196.65		1.125	420.4		1.375	800.22
	.875	230.5		1.25	468.65	60	1	597.92
	1	264.65	38	.75	284.86		1.125	674.01
	.625	169.23		.875	333 41		1 25	750.45
	.75	204		1	382.27		1.375	827.17
	.875	239.07		1.125	431.41	65	1	646.93
	1	274.45		1.25	480.89		1.125	729.18
	.625	175.36	39	.75	292.21		1.25	811.73
	.75	211.35		.875	341.97		1.375	894.6
	.875	247.65		1	392.08	70	1	695.92
	1	284.25		1.125	442.44		1.25	872.98
	.625	181.49		1.25	493.14		1.5	1051.25

Equivalent Length of Pipe for a Socket.

$\frac{d}{15} = l$. *d representing diameter of pipe and l length in inches*

ional weight of two flanges for any diameter is computed equal :he pipe.

—*These weights do not include any allowance for spigot and so* *or rule to compute thicknesses of pipes, flanges, etc., see page 5*

Weight of Flat Rolled Bar Steel. (*D. K. Clark.*)

From .5 Inch to 8 Inches in Width. ONE FOOT IN LENGTH.

WIDTH IN INCHES.

Thickness.	.5	.625	.75	.875	1	1.25	1.5	1.75	2	2.25	2.5	2.75
Inch.	Lb.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/4	.425	.533	.64	.743	.85	1.06	1.28	1.49	1.7	1.91	2.13	2.34
5/16	.531	.665	.8	.929	1.06	1.33	1.59	1.86	2.13	2.39	2.66	2.92
3/8	.638	.798	.96	1.11	1.28	1.59	1.91	2.23	2.55	2.87	3.19	3.51
7/16	.744	.931	1.12	1.3	1.49	1.86	2.23	2 6	2.98	3.35	3.72	4.09
1/2	.85	1.06	1.28	1.49	1.7	2.13	2.55	2.98	3.4	3.83	4.25	4.68
9/16	—	1.2	1.44	1.67	1.91	2.39	2.87	3.35	3.83	4.3	4.78	5.26
5/8	—	1.33	1.6	1.86	2.12	2.66	3.19	3.72	4.25	4.78	5.31	5.84
11/16	—	—	1.76	2.04	2.34	2.92	3.51	4.09	4.68	5.26	5.84	6.43
3/4	—	—	1.92	2.23	2.55	3.19	3.83	4.46	5.	5.74	6.38	7.01
13/16	—	—	—	2.41	2.76	3.45	4.14	4.83	5.53	6.22	6.91	7.6
7/8	—	—	—	2.6	2.98	3.72	4.46	5.21	5.95	6.69	7.44	8.18
15/16	—	—	—	—	3.19	3 98	4.78	5 58	6.38	7.17	7.97	8.77
1	—	—	—	—	3.4	4.25	5.1	5.95	6.8	7.65	8.5	9.35

WIDTH IN INCHES.

Thickness.	3	3.25	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/4	2.55	2.76	2.98	3.4	3 82	4.26	4.68	5.1	5.52	5 96	6.38	6.8
5/16	3.19	3.45	3.72	4.25	4.78	5.32	5.84	6.38	6.9	7.44	7.97	8.5
3/8	3.83	4 14	4 46	5.1	5.74	6.38	7.02	7.66	8.28	8.92	9.56	10.2
7/16	4.46	4.83	5.21	5.95	6.7	7.44	8.18	8.92	9.66	10.4	11.2	11.9
1/2	5.1	5.53	5 95	6.8	7.66	8 5	9.36	10.2	1.1	11.9	12.8	13.6
9/16	5.74	6.22	6.69	7.65	8 6	9.56	10.5	11.5	12.4	13 4	14.3	15.3
5/8	6.38	6.91	7.44	8.5	9.56	10.6	11.7	12.8	13.8	14 9	-5.9	17
11/16	7.01	7.6	8.18	9.35	10.5	11.7	12.9	14	15.2	16.4	17.5	18.7
3/4	7.65	8.29	8 93	10.2	11.5	12.8	14	15.3	16.6	17.9	19.1	20.4
13/16	8.29	8.98	9.67	11.1	12 4	13.8	15.2	16.6	18	19.3	20.7	22.2
7/8	8.93	9.67	10.4	11.9	13.4	14.9	16.4	17.9	19.4	20.8	22.3	23.8
15/16	9.56	10.4	11.2	12.8	14.3	15.9	17.5	19.1	20.8	22.4	23.9	25.6
1	10.2	11.1	.9	13.6	15.3	17	18.7	20.4	22.1	23.8	25.5	27.2

Weight of Rolled Square Steel.

From .125 Inch to 6 Inches Square. ONE FOOT IN LENGTH.

Side.	Weight.	Side.	Weight.	Side.	Weight.	Side.	Weight.	Side.	Weight.
Inch.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
.125	.053	.75	1.92	1.375	6.43	2.125	15.4	3.75	47.8
.1875	.119	.8125	2.24	1.4375	7.03	2.25	17.2	4	54.4
.25	.212	.875	2.6	1.5	7.65	2.375	19.2	4.25	61.4
.3125	.333	.9375	3.06	1.5625	8 3	2.5	21.2	4.5	68.9
.375	.478	1	3 4	1.625	8 98	2.625	23.5	4.75	76.7
.4375	.651	1.0625	3.83	1.6875	9.79	2.75	25.7	5	85
.5	.85	1.125	4.3	1.75	10.4	2.875	28.2	5.25	93.7
[illegible]		·1875	4.79	1.8125	11.2	3	30.6	5 5	102.8
		:	5.31	1.875	11.9	3.25	35.9	5 75	112 4
		15	5 86	2	13.6	3.5	41.6	6	122.4

Weight of Round Rolled Steel.

From .125 Inch to 12 Inches Diameter. ONE FOOT IN LENGTH.

am.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diam.	Weight.	Diam.	Weight.
:h.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
5	.0417	.875	2.04	1.625	7.05	2.875	22	5.75	88.3
75	.0939	.9375	2.35	1.6875	7.61	3	24.1	6	96.1
	.167	1	2.67	1.75	8.18	3.25	28.3	6.5	113.2
25	.26	1.0625	3	1.8125	8.77	3 5	32 7	7	130.8
5	.375	1.125	3.38	1.875	9.38	3.75	34.2	7.5	136.8
75	.511	1.1875	3.76	2	10.7	4	42.7	8	170.8
	.667	1.25	4.17	2.125	12	4.25	48.3	8.5	193.2
25	.845	1.3125	4.6	2.25	13.6	4.5	54.6	9	218.4
5	1.04	1.375	5.05	2.375	15.1	4.75	60.3	9.5	241.2
75	1.27	1.4375	5.18	2.5	16.7	5	66.8	10	267.2
	1.5	1.5	6.01	2.625	18.4	5.25	73.6	11	323
25	1.76	1.5625	6.52	2.75	20.2	5.5	80.8	12	384.3

Weight of Hexagonal, Octagonal, and Oval Steel.

ONE FOOT IN LENGTH.

HEXAGONAL.				OCTAGONAL.				OVAL.		
ı. r L.	Weight.	Diam. over Sides.	Weight.	Diam. over Sides.	Weight.	Diam. over Sides.	Weight.	Diam. over Sides.	Area.	Weight.
.	Lbs.	Ins.	Lbs.	Inch.	Lbs.	Ins.	Lbs.	Ins.	Sq. In.	Lbs.
	.414	1	2.94	⅝	.396	1	2.82	¾ × ⅜	.251	.853
	.736	1⅛	3.73	½	.704	1⅛	3.56	⅞ × ½	.344	1.17
	1.15	1¼	4.6	⅝	1.1	1¼	4.4	1 × ½	.446	1.52
	1.66	1⅜	5.57	¾	1.58	1⅜	5.32	1¼ × ⅝	.697	2.37
	2.25	1½	6.63	⅞	2.16	1½	6.34	1½ × ¾	.884	3

Weight of a Square Foot of Sheet Copper.

Wire Gauge of Wm. Foster & Co. (England.)

hickness.		Weight.	Thickness.		Weight.	Thickness.		Weight.
.	Inch.	Lbs.	W. G.	Inch.	Lbs.	W. G.	Inch.	Lbs.
	.306	14	11	.123	5.65	21	.034	1.55
	.284	13	12	.109	5	22	.029	1.35
	.262	12	13	.098	4.5	23	.025	1.15
	.24	11	14	.088	4	24	.022	1
	.222	10.15	15	.076	3.5	25	.019	.89
	.203	9.3	16	.065	3	26	.017	.79
	.186	8.5	17	.057	2.6	27	.015	.7
	.168	7.7	18	.049	2.25	28	.013	.62
	.153	7	19	.044	2	29	.012	.56
	.138	6.3	20	.038	1.75	30	.011	.5

Weight of Composition Sheathing Nails.

ength.	Number in a Pound.	No.	Length.	Number in a Pound.	No.	Length.	·th.	Number in a Pound.
Inch.			Ins.			Ins.		
.75	290	4	1.125	201	7	1.125		101
.875	260	5	1.25	199	8	1.25		
	212	6	1	190	9	1.5		

Weight of Flat Rolled ... Iron, ... Sectional

From .5 Inch to 8 Inches in W... ... Foot.

WIDTH

Thickness.	.5	.625	.75	.875
Inch.	Lb.	Lbs.	Lbs.	Lbs.
1/4	.425	.533	.64	.743
5/16	.531	.665	.8	.929
3/8	.638	.798	.96	1.11
7/16	.744	.931	1.12	1.3
1/2	.85	1.06	1.28	[illegible]
9/16	—	1.2	1.44	[illegible]
5/8	—	1.33	1.6	[illegible]
11/16	—	—	1.76	[illegible]
3/4	—	—	1.9	[illegible]
13/16	—	—	—	[illegible]
7/8	—	—	—	[illegible]
15/16	—	—	—	[illegible]
1	—	—	—	[illegible]

Thickness.	3
Inch.	Lbs.
1/4	2.5
5/16	3.1

2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7

6.042, 6.378, 6.714, 7.049, 7.385, 7.721, 8.056, 8.392, 8.728, 9.063, 9.399, 9.734, 10.07, 10.41, 10.74, 11.08, 11.41, 11.75, 12.08, 12.42, 12.76, 13.09, 13.43, 13.76, 14.1, 14.43, 14.77, 15.11, 15.44, 15.78

3.754, 4.067, 4.38, 4.693, 5.006, 5.319, 5.632, 5.945, 6.258, 6.57, 6.883, 7.196, 7.509, 7.822, 8.135, 8.448, 8.76, 9.073, 9.386, 9.699, 10.01, 10.32, 10.64, 10.95, 11.26, 11.58, 11.89, 12.2, 12.51, 12.83, 13.14, 13.45, 13.77, 14.08, 14.39, 14.7, 15.02, 15.33

2.371, 2.71, 3.049, 3.387, 3.726, 4.065, 4.404, 4.742, 5.081, 5.42, 5.759, 6.097, 6.436, 6.775, 7.114, 7.452, 7.791, 8.13, 8.469, 8.807, 9.146, 9.485, 9.824, 10.16, 10.5, 10.84, 11.18, 11.52, 11.86, 12.19, 12.53, 12.87, 13.21, 13.55, 13.89, 14.23, 14.57, 14.91, 15.24, 15.58, 15.92, 16.26, 16.6, 16.94

1.5, 1.92, 2.312, 2.698, 3.083, 3.469, 3.854, 4.24, 4.625, 5.01, 5.396, 5.781, 6.167, 6.552, 6.937, 7.323, 7.708, 8.094, 8.474, 8.864, 9.25, 9.635, 10.02, 10.41, 10.79, 11.18, 11.56, 11.95, 12.33, 12.72, 13.1, 13.49, 13.87, 14.26, 14.64, 15.03, 15.42, 15.8, 16.19, 16.57, 16.96, 17.34, 17.73, 18.11, 18.5, 18.88, 19.27

4., 4.9, 5.414, 5.906, 6.398, 6.89, 7.383, 7.875, 8.367, 8.859, 9.351, 9.843, 10.33, 10.83, 11.32, 11.81, 12.3, 12.8, 13.29, 13.78, 14.27, 14.76, 15.26, 15.75, 16.24, 16.73, 17.22, 17.72, 18.21, 18.7, 19.19, 19.69, 20.18, 20.67, 21.16, 21.65, 22.15, 22.64, 23.13, 23.62, 24.12, 24.61

Weight of English Angle and T Iron. (*D. K. Cla*

ONE FOOT IN LENGTH.

NOTE.—When base or web tapers in section, mean thickness is to be measured.

Thickness.	SUM OF WIDTH AND DEPTH IN INCHES.										
	1.5	1.625	1.75	1.875	2	2.125	2.25	2.375	2.5	2.625	2.75
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
.125	.57	.62	.68	.73	.78	.83	.88	.94	.99	1.04	1.09
.1875	.81	.89	.97	1.05	1.13	1.21	1.29	1.37	1.45	1.52	1.6
.25	1.04	1.15	1.25	1.36	1.46	1.56	1.67	1.77	1.88	1.98	2.08
.3125	1.24	1.37	1.5	1.63	1.76	1.89	2.02	2.15	2.28	2.41	2.54
	2.875	3	3.125	3.25	3.375	3.5	3.625	3.75	3.875	4	4.25
.125	1.14	1.2	1.25	1.3	1.45	1.41	1.46	1.51	1.56	1.62	1.72
.1875	1.68	1.76	1.84	1.91	1.99	2.07	2.15	2.23	2.3	2.38	2.54
.25	2.19	2.29	2.4	2.5	2.6	2.71	2.81	2.92	3.02	3.13	3.33
.3125	2.67	2.8	2.93	3.06	3.19	3.32	3.45	3.58	3.71	3.84	4.1
.375	3.13	3.28	3.44	3.59	3.75	3.91	4.06	4.22	4.38	4.53	4.84
.4375	3.57	3.75	3.93	4.11	4.29	4.48	4.66	4.84	5.02	5.2	5.56
	4.5	4.75	5	5.25	5.5	5.75	6	6.25	6.5	6.75	7
.1875	2.7	2.85	3.01	3.16	3.32	3.48	3.63	3.79	3.95	4.1	4.26
.25	3.54	3.75	3.96	4.17	4.38	4.[illegible]	4.79	5	5.21	5.42	5.63
.3125	4.36	4.62	4.88	5.14	5.4	5.66	5.92	6.18	6.45	6.71	6.97
.375	5.16	5.47	5.78	6.09	6.41	6.72	7.03	7.34	7.66	7.97	8.28
.4375	5.92	6.29	6.65	7.02	7.38	7.75	8.11	8.48	8.84	9.21	9.57
.5	6.67	7.08	7.5	7.92	8.33	8.75	9.17	9.58	10	10.42	10.83
.5625	7.38	7.85	8.32	8.79	9.26	9.73	10.2	10.66	11.13	12.6	12.07
	7.25	7.5	7.75	8	8.25	8.5	8.75	9	9.25	9.5	9.75
.25	5.83	6.04	6.25	6.46	6.67	6.88	7.08	7.29	7.5	7.71	7.92
.3125	7.23	7.49	7.75	8.01	8.27	8.53	8.79	9.05	9.31	9.57	9.83
.375	8.59	8.91	9.22	9.53	9.84	10.16	10.47	10.78	11.09	11.41	11.72
.4375	9.93	10.3	10.66	11.03	11.39	11.76	12.12	12.49	12.85	13.22	13.58
.5	11.25	11.67	12.08	12.5	12.92	13.33	13.75	14.17	14.58	15	15.42
.5625	12.54	13.01	13.48	13.94	14.41	14.88	15.35	15.82	16.29	16.76	17.23
.625	13.8	14.32	14.84	15.36	15.89	16.41	16.93	17.45	17.97	18.49	19.01
	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
.375	12.03	12.66	13.28	13.91	14.53						
.4375	13.95	14.67	15.4	16.13	16.86	17.59	18.31	19.04	19.77	20.5	21.22
.5	15.83	16.67	17.5	18.33	19.17	20	20.84	21.67	22.5	23.34	24.17
.5625	17.7	18.63	19.57	20.51	21.44	22.38	23.31	24.25	25.19	26.12	27.06
.625	19.53	20.57	21.61	22.66	23.7	24.74	25.78	26.83	27.87	28.91	29.95
.75	23.13	24.38	25.63	26.88	28.13	29.37	30.63	31.88	33.13	34.38	35.63
	12	12.5	13	13.5	14	15	16	17	18	19	20
.625	23.7	24.74	25.78	26.83	27.87	29.95	32.03	34.12	36.2	38.28	40.36
.75	28.13	29.37	30.63	31.88	33.13	35.63	38.13	40.63	41.13	43.63	46.13
.875	32.45	33.91	35.36	36.82	38.28	41.19	44.12	47.02	49.95	52.87	55.78
1	36.67	38.33	40	41.67	43.33	46.67	50	53.33	56.67	60	63.33

NOTE.—American rolled is slightly heavier.

Weight of Cast and Wrought Iron, Steel, Copper, and Brass, of a given Sectional Area.

PER LINEAL FOOT.

Sectional Area.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Lead.	Brass.	Gun-metal
Sq. Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
.1	·336	·313	·339	·385	·492	·357	·38
.2	.671	.626	.677	·771	·984	·713	·759
·3	1.007	·939	1.016	1.156	1.476	1.07	1.139
·4	1.343	1.251	1.355	1.542	1.967	1.427	1.519
·5	1.678	1.564	1.694	1.927	2.461	1.783	1.89[illegible]
.6	2.014	1.877	2.032	2.312	2.953	2.14	2.279
·7	2.35	2.19	2.371	2.698	3.445	2.497	2.658
.8	2.685	2.503	2.71	3.083	3.937	2.853	3.038
.9	3.021	2.816	3.049	3.469	4.429	3.21	3.418
1	3.357	3.129	3.387	3.854	4.922	3.567	3.798
1.1	3.692	3.442	3.726	4.24	5.414	3.923	4.177
1.2	4.028	3.754	4.065	4.625	5.906	4.28	4.557
1.3	4.364	4.067	4.404	5.01	6.398	4.636	4.937
1.4	4.699	4.38	4.742	5.396	6.89	4.993	5.317
1.5	5.035	4.693	5.081	5.781	7.383	5.35	5.696
1.6	5.371	5.006	5.42	6.167	7.875	5.707	6.076
1.7	5.706	5.319	5.759	6.552	8.367	6.063	6.456
1.8	6.042	5.632	6.097	6.937	8.859	6.42	6.836
1.9	6.378	5.945	6.436	7.323	9.351	6.777	7.215
2	6.714	6.258	6.775	7.708	9.843	7.133	7.595
2.1	7.049	6.57	7.114	8.094	10.33	7.49	7.97
2.2	7.385	6.883	7.452	8.474	10.83	7.847	8.35
2.3	7.721	7.196	7.791	8.864	11.32	8.203	8.73
2.4	8.056	7.509	8.13	9.25	11.81	8.56	9.11
2.5	8.392	7.822	8.469	9.635	12.3	8.917	9.49
2.6	8.728	8.135	8.807	10.02	12.8	9.273	9.87
2.7	9.063	8.448	9.146	10.41	13.29	9.63	10.25
2.8	9.399	8.76	9.485	10.79	13.78	9.98	10.63
2.9	9.734	9.073	9.824	11.18	14.27	10.34	11.01
3	10.07	9.386	10.16	11.56	14.76	10.7	11.39
3·1	10.41	9.699	10.5	11.95	15.26	11.06	11.77
3·2	10.74	10.01	10.84	12.33	15.75	11.41	12.15
3·3	11.08	10.32	11.18	12.72	16.24	11.77	12.53
3·4	11.41	10.64	11.52	13.1	16.73	12.13	12.91
3·5	11.75	10.95	11.86	13.49	17.22	12.48	13.29
3·6	12.08	11.26	12.19	13.87	17.72	12.84	13.67
3·7	12.42	11.58	12.53	14.26	18.21	13.2	14.05
3·8	12.76	11.89	12.87	14.64	18.7	13.55	14.43
3·9	13.09	12.2	13.21	15.03	19.19	13.91	14.81
4	13.43	12.51	13.55	15.42	19.69	14.27	15.19
4·1	13.76	12.83	13.89	15.8	20.18	14.62	15.57
4·		13.14	14.23	16.19	20.67	14.98	15.95
		13.45	14.57	16.57	21.16	15.34	16.33
		13.77	14.91	16.96	21.65	15.69	16.71
		14.08	15.24	17.34	22.15	16.05	17.09
		14.39	15.58	17.73	22.64	16.41	17.47
		14.7	15.92	18.11	23.13	16.76	17.85
		15.02	16.26	18.5	23.62	17.12	18.23
		15.33	16.6	18.88	24.12	17.48	18.61
		15.64	16.94	19.27	24.61	17.83	18.99

7eight of Lead and Tin Lined Pipe per Foot.

From .375 Inch to 5 Inches in Diameter. (Tatham & Bros.)

WASTE-PIPE.				BLOCK-TIN PIPE.					
ım.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
s.	Lbs.	Ins.	Lbs.	Inch.	Lb.	Inch.	Lbs.	Ins.	Lbs.
5	2	4	8	.375	.3594	.625	.5	1.25	1.25
	3	4.5	6	.375	.375	.625	.625	1.25	1.5
	3.5	4.5	8	.375	.5	.75	.625	1.5	2
	5	5	8	.5	.375	.75	.75	1.5	2.5
	5	5	10	.5	.5	1	.9375	2	2.5
	6	5	12	.5	.625	1	1.125	2	3

WATER-PIPE.

From .375 Inch to 5 Inches in Diameter.

Thickness.	Weight.	Diam.	Thickness.	Weight.	Diam.	Thickness.	Weight.	Diam.	Thickness.	Weight.
Inch.	Lbs.	Ins.	Inch.	Lbs.	Ins.	Inch.	Lbs.	Ins.	Inch.	Lbs.
.08	.625	.625	.25	3.5	1.25	.19	4.75	2.5	.3125	14
.12	1	.75	.1	1.25	1.25	.25	6	2.5	.375	17
.16	1.25	.75	.12	1.75	1.5	.12	3	3	.1875	9
.19	1.5	.75	.16	2.25	1.5	.14	3.5	3	.25	12
.34	2.5	.75	.2	3	1.5	.17	4.25	3	.3125	16
.07	.0545	.75	.23	3.5	1.5	.19	5	3	.375	20
.09	.75	.75	.3	4.75	1.5	.23	6.5	3.5	.1875	9.5
.11	1	1	.1	1.5	1.5	.27	8	3.5	.25	15
.13	1.25	1	.11	2	1.75	.13	4	3.5	.3125	18.5
.16	1.75	1	.14	2.5	1.75	.17	5	3.5	.375	22
.19	2	1	.17	3.25	1.75	.21	6.5	4	.1875	12.5
.25	3	1	.21	4	1.75	.27	8.5	4	.25	16
.08	.0727	1	.24	4.75	2	.15	4.75	4	.3125	21
.09	1	1	.3	6	2	.18	6	4	.375	25
.13	1.5	1.25	.1	2	2	.22	7	4.5	.1875	14
.16	2	1.25	.12	2.5	2	.27	9	4.5	.25	18
.2	2.5	1.25	.14	3	2.5	.1875	8	5	.25	20
.22	2.75	1.25	.16	3.75	2.5	.25	11	5	.375	31

Marks and Weight of Tin-plates. (*English.*)

ARK BRAND.	Plates per Box.	Dimensions.	Weight per Box.	MARK OR BRAND.	Plates per Box.	Dimensions.	Weight per Box.
	No.	Ins.	No.		No.	Ins.	No.
1 Com.	225	13.75×10	112	DXXXX.....	100	16.75×12.5	189
......	225	13.25× 9.75	105	SDC.........	200	15 ×11	168
......	225	12.75× 9.5	98	SDX.........	200	15 ×11	188
......	225	13.75×10	119	SDXX........	200	15 ×11	209
......	225	13.75×10	157	SDXXX......	200	15 ×11	230
......	225	13.75×10	140	SDXXXX....	200	15 ×11	251
......	225	13.25× 9.75	133	SDXXXXX.	200	15 ×11	272
......	225	12.75× 9.5	126	SDXXXXXX.	200	15 ×11	293
......	225	13.75×10	161	Leaded IC...	112	20 ×14	112
......	225	13.75×10	182	" IX...	112	20 ×14	140
X....	225	13.75×10	203	ICW........	225	13.75×10	112
XX..	225	13.75×10	224	IXW........	225	13.75×10	140
XXX.	225	13.75×10	245	CSDW.......	200	15 ×	3
......	100	16.75×12.5	98	CIIW........	100	16.75	
......	100	16.75×12.5	126	XIIW.......	100	16.75	
......	100	16.75×12.5	147	TT..........	450	13.7	
.....	100	16.75×12.5	168	XTT........	450	13.	

When the plates are 14 by 20 inches, there are 112 in a

Weight of Cast and Wrought Iron, Steel, Coppe Brass, of a given Sectional Area.

Per Lineal Foot.

Sectional Area.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Lead.	Brass.
Sq. Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
.1	.336	.313	.339	.385	.492	.357
.2	.671	.626	.677	.771	.984	.713
.3	1.007	.939	1.016	1.156	1.476	1.07
.4	1.343	1.251	1.355	1.542	1.967	1.427
.5	1.678	1.564	1.694	1.927	2.461	1.783
.6	2.014	1.877	2.032	2.312	2.953	2.14
.7	2.35	2.19	2.371	2.698	3.445	2.497
.8	2.685	2.503	2.71	3.083	3.937	2.853
.9	3.021	2.816	3.049	3.469	4.429	3.21
1	3.357	3.129	3.387	3.854	4.922	3.567
1.1	3.692	3.442	3.726	4.24	5.414	3.923
1.2	4.028	3.754	4.065	4.625	5.906	4.28
1.3	4.364	4.067	4.404	5.01	6.398	4.636
1.4	4.699	4.38	4.742	5.396	6.89	4.993
1.5	5.035	4.693	5.081	5.781	7.383	5.35
1.6	5.371	5.006	5.42	6.167	7.875	5.707
1.7	5.706	5.319	5.759	6.552	8.367	6.063
1.8	6.042	5.632	6.097	6.937	8.859	6.42
1.9	6.378	5.945	6.436	7.323	9.351	6.777
2	6.714	6.258	6.775	7.708	9.843	7.133
2.1	7.049	6.57	7.114	8.094	10.33	7.49
2.2	7.385	6 883	7.452	8.474	10.83	7.847
2.3	7.721	7.196	7.791	8.864	11.32	8.203
2.4	8.056	7.509	8.13	9.25	11.81	8.56
2.5	8.392	7.822	8.469	9.635	12.3	8.917
2.6	8.728	8.135	8.807	10.02	12.8	9.273
2.7	9.063	8.448	9.146	10.41	13.29	9 63
2.8	9.399	8.76	9.485	10.79	13.78	9.98
2.9	9.734	9.073	9.824	11.18	14.27	10.34
3	10.07	9.386	10.16	11.56	14.76	10.7
3.1	10.41	9.699	10.5	11.95	15.26	11.06
3.2	10.74	10.01	10.84	12.33	15.75	11.41
3.3	11.08	10.32	11.18	12.72	16.24	11.77
3.4	11.41	10.64	11.52	13.1	16.73	12.13
3.5	11.75	10.95	11.86	13.49	17.22	12.48
3.6	12.08	11.26	12.19	13.87	17.72	12.84
3.7	12.42	11.58	12.53	14.26	18.21	13.2
3.8	12.76	11.89	12.87	14.64	18.7	13.55
3.9	13.09	12.2	13.21	15.03	19.19	13.91
4	13.43	12.51	13.55	15.42	19.69	14.27
4.1	13.76	12.83	13.89	15.8	20.18	14.62
4.2	14.1	13.14	14.23	16.19	20.67	14.98
4.3	14.43	13.45	14.57	16.57	21.16	15.34
4.4	14.77	13.77	14.91	16.96	21.65	15.69
4.5	15.11	14.08	15.24	17.34	22.15	16.05
4.6	15.44	14.39	15.58	17.73	22.64	16.41
[illegible]	15.78	14.7	15.92	18.11	23.13	16.76
[illegible]	[illegible]11	15.02	16.26	18.5	23.62	17.12
[illegible]	[illegible]5	15.33	16.6	18.88	24.12	17.48
[illegible]	[illegible]	15.64	16.94	19.27	24.61	17.83

'eight of Lead and Tin Lined Pipe per Foot.

From .375 Inch to 5 Inches in Diameter. (Tatham & Bros.)

WASTE-PIPE.				BLOCK-TIN PIPE.					
m.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
ı.	Lbs.	Ins.	Lbs.	Inch.	Lb.	Inch.	Lbs.	Ins.	Lbs.
5	2	4	8	.375	.3594	.625	.5	1.25	1.25
	3	4.5	6	.375	.375	.625	.625	1.25	1.5
	3.5	4.5	8	.375	.5	.75	.625	1.5	2
	5	5	8	.5	.375	.75	.75	1.5	2.5
	5	5	10	.5	.5	1	.9375	2	2.5
	6	5	12	.5	.625	1	1.125	2	3

WATER-PIPE.

From .375 Inch to 5 Inches in Diameter.

.	Thickness.	Weight.	Diam.	Thickness.	Weight.	Diam.	Thickness.	Weight.	Diam.	Thickness.	Weight.
.	Inch.	Lbs.	Ins.	Inch.	Lbs.	Ins.	Inch.	Lbs.	Ins.	Inch.	Lbs.
	.08	.625	.625	.25	3.5	1.25	.19	4.75	2.5	.3125	14
	.12	1	.75	.1	1.25	1.25	.25	6	2.5	.375	17
	.16	1.25	.75	.12	1.75	1.5	.12	3	3	.1875	9
	.19	1.5	.75	.16	2.25	1.5	.14	3.5	3	.25	12
	.34	2.5	.75	.2	3	1.5	.17	4.25	3	.3125	16
	.07	.0545	.75	.23	3.5	1.5	.19	5	3	.375	20
	.09	.75	.75	.3	4.75	1.5	.23	6.5	3.5	.1875	9.5
	.11	1	1	.1	1.5	1.5	.27	8	3.5	.25	15
	.13	1.25	1	.11	2	1.75	.13	4	3.5	.3125	18.5
	.16	1.75	1	.14	2.5	1.75	.17	5	3.5	.375	22
	.19	2	1	.17	3.25	1.75	.21	6.5	4	.1875	12.5
	.25	3	1	.21	4	1.75	.27	8.5	4	.25	16
	.08	.0727	1	.24	4.75	2	.15	4.75	4	.3125	21
	.09	1	1	.3	6	2	.18	6	4	.375	25
	.13	1.5	1.25	.1	2	2	.22	7	4.5	.1875	14
	.16	2	1.25	.12	2.5	2	.27	9	4.5	.25	18
	.2	2.5	1.25	.14	3	2.5	.1875	8	5	.25	20
	.22	2.75	1.25	.16	3.75	2.5	.25	11	5	.375	31

Marks and Weight of Tin-plates. (*English.*)

ıRK BAND.	Plates per Box.	Dimensions.	Weight per Box.	MARK OR BRAND.	Plates per Box.	Dimensions.	Weight per Box.
	No.	Ins.	No.		No.	Ins.	No.
1 Com.	225	13.75×10	112	DXXXX.....	100	16.75×12.5	189
......	225	13.25× 9.75	105	SDC.........	200	15 ×11	168
......	225	12.75× 9.5	98	SDX........	200	15 ×11	188
......	225	13.75×10	119	SDXX.......	200	15 ×11	209
......	225	13.75×10	157	SDXXX......	200	15 ×11	230
......	225	13.75×10	140	SDXXXX....	200	15 ×11	251
......	225	13.25× 9.75	133	SDXXXXX.	200	15 ×11	272
......	225	12.75× 9.5	126	SDXXXXXX.	200	15 ×11	293
......	225	13.75×10	161	Leaded IC...	112	20 ×14	112
......	225	13.75×10	182	" IX...	112	20 ×14	140
X....	225	13.75×10	203	ICW	225	13.75×10	112
XX..	225	13.75×10	224	IXW........	225	13.75×10	140
XXX.	225	13.75×10	245	CSDW.......	200	15	
......	100	16.75×12.5	98	CIIW........	100	16.7	
......	100	16.75×12.5	126	XIIW	100	16.7	
......	100	16.75×12.5	147	TT..........	450	13.	
......	100	16.75×12.5	168	XTT........	450	13.	

When the plates are 14 by 20 inches, there are 112 in a

Iron Welded Steam, Gas, and Water Pipe.

STANDARD DIMENSIONS.

National Tube Works Company.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Sq. Foot of Surface.		Length containing one Cubic Foot.	Weight
Internal.	External.	Actual Int'nal.		External.	Internal.	External.	Internal.	Metal.	External.	Internal.		
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet.	Feet.	Feet.	Lbs.
.125	.4	.27	.07	1.27	.85	.13	.06	.07	9.44	14.15		[illegible]
.25	.54	.36	.09	1.7	1.14	.23	.1	.12	7.07	10.49		[illegible]
.375	.67	.49	.09	2.12	1.55	.36	.19	.17	5.66	7.73	751.2	[illegible]
.5	.84	.62	.11	2.64	1.96	.55	.3	.25	4.55	6.13	472.4	[illegible]
.75	1.05	.82	.11	3.3	2.59	.87	.53	.33	3.64	4.63	270	1.
1	1.31	1.05	.13	4.13	3.29	1.36	.86	.49	2.9	3.64	166.9	1.6
1.25	1.66	1.38	.14	5.21	4.33	2.16	1.5	.67	2.3	2.77	96.2	2.
1.5	1.9	1.61	.14	5.97	5.06	2.83	2.04	.8	2.01	2.37	70.7	2.6
2	2.37	2.07	.15	7.46	6.49	4.43	3.36	1.07	1.61	1.85	42.9	3.6
2.5	2.87	2.47	.20	9.03	7.75	6.49	4.78	1.71	1.33	1.55	30.1	5.
3	3.5	3.07	.22	11	9.64	9.62	7.39	2.24	1.09	1.24	19.5	7.
3.5	4	3.55	.23	12.57	11.15	12.57	9.89	2.68	.95	1.08	14.6	9
4	4.5	4.03	.24	14.14	12.65	15.9	12.73	3.17	.85	.95	11.3	10.6
4.5	5	4.51	.25	15.71	14.16	19.63	15.96	3.67	.76	.85	9	12.
5	5.56	5.04	.26	17.48	15.85	24.31	19.99	4.32	.69	.76	7.2	14.
6	6.62	6.06	.28	20.81	19.05	34.47	28.89	5.58	.58	.63	5	18.
7	7.62	7.02	.30	23.95	22.06	45.66	38.74	6.93	.5	.54	3.7	23.
8	8.62	7.98	.32	27.1	25.08	58.43	50.04	8.39	.44	.48	2.9	28.1
9	9.62	8.94	.34	30.24	28.08	72.76	62.73	10.03	.4	.43	2.3	33.
10	10.75	10.02	.37	33.77	31.48	90.76	78.84	11.92	.35	.38	1.8	40.
11	12	11.25	.37	37.7	35.34	113.1	99.4	13.7	.32	.34	1.5	45.9
12	12.75	12	.37	40.06	37.7	127.68	113.1	14.58	.3	.32	1.3	48.9
13	14	13.25	.37	43.98	41.63	153.94	137.89	16.05	.27	.29	1	53.9
14	15	14.25	.37	47.12	44.77	176.72	159.49	17.23	.26	.27	.9	57.8
15	16	15.25	.37	50.27	47.91	201.06	182.66	18.41	.24	.25	.8	61.7
—	18	17.25	.37	56.55	54.19	254.47	233.71	20.76	.21	.22	.6	69.6
—	20	19.25	.37	62.83	60.48	314.16	291.04	23.12	.19	.20	.5	77.5
—	22	21.25	.37	69.12	66.76	380.13	354.66	25.48	.17	.18	.4	85.4
—	24	23.25	.37	75.4	73.04	452.39	424.56	27.83	.16	.16	.3	93.3

Lap-welded Steel, Semi-steel, Special Locomotive and Franklinite Boiler-Tubes.

STANDARD DIMENSIONS. *National Tube Works Company.*

Diameter.		Thickness.	Wire Gauge.	Circumference.		Transverse Areas.			Length per Sq. Foot of Surface.		Weight per Foot.
External.	Internal.			External.	Internal.	External.	Internal.	Metal.	External.	Internal.	
Ins.	Ins.	Ins.	No.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet.	Feet.	Lbs.
1	.834	.083	14	3.142	2.62	.785	.546	.239	3.82	4.58	.8
1.25	1.084	.083	14	3.927	3.405	1.227	.923	.304	3.056	3.524	1.0
[illegible]	[illegible]	.095	13	4.712	4.115	1.767	1.348	.419	2.546	2.916	1.4
[illegible]	[illegible]	.109	12	5.498	4.813	2.405	1.843	.562	2.183	2.493	1.9
[illegible]	[illegible]	[illegible]	12	6.283	5.598	3.142	2.494	.648	1.91	2.144	2.2
[illegible]	[illegible]	[illegible]	[illegible]	7.069	6.384	3.976	3.243	.733	1.698	1.88	2.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.1	4.909	4.011	.898	1.528	1.69	3.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.885	5.94	4.948	.992	1.389	1.522	3.3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.67	7.069	5.983	1.086	1.273	1.384	3

Lap Welded Charcoal Iron Boiler Tubes.

Standard Dimensions.

National Tube Works Company.

iameter.		Thickness.	Wire Gauge.	Circumference.		Transverse Areas.			Length per Sq. Foot of Surface.		Weight per Foot.
al.	Internal.			External.	Internal.	External.	Internal.	Metal.	External.	Internal.	
.	Ins.	Ins.	No.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet.	Feet.	Lbs.
	.86	.072	15	3.14	2.69	.78	.57	.21	3.82	4.46	.71
25	.98	.072	15	3.53	3.08	.99	.76	.24	3.39	3.89	.8
5	1.11	.072	15	3.93	3.47	1.23	.96	.27	3.06	3.45	.89
2	1.15	.083	14	4.12	3.6	1.35	1.03	.32	2.91	3.33	1.08
75	1.21	.083	14	4.32	3.8	1.48	1.15	.34	2.78	3.16	1.13
	1.33	.083	14	4.71	4.19	1.77	1.4	.37	2.55	2.86	1.24
25	1.43	.095	13	5.1	4.51	2.07	1.62	.46	2.35	2.66	1.53
5	1.56	.095	13	5.5	4.9	2.4	1.91	.49	2.18	2.45	1.66
75	1.68	.095	13	5.89	5.29	2.76	2.23	.53	2.04	2.27	1.78
	1.81	.095	13	6.28	5.69	3.14	2.57	.57	1.91	2.11	1.91
25	1.93	.095	13	6.68	6.08	3.55	2.94	.61	1.8	1.97	2.04
	2.06	.095	13	7.07	6.47	3.98	3.33	.64	1.7	1.85	2.16
5	2.16	.109	12	7.46	6.78	4.43	3.65	.78	1.61	1.77	2.61
	2.28	.109	12	7.85	7.17	4.91	4.09	.82	1.53	1.67	2.75
	2.53	.109	12	8.64	7.95	5.94	5.03	.9	1.39	1.51	3.04
5	2.66	.109	12	9.03	8.35	6.49	5.54	.95	1.33	1.44	3.18
	2.78	.109	12	9.42	8.74	7.07	6.08	.99	1.27	1.37	3.33
	3.01	.12	11	10.21	9.46	8.3	7.12	1.18	1.17	1.26	3.96
	3.26	.12	11	11	10.24	9.62	8.35	1.27	1.09	1.17	4.28
	3.51	.12	11	11.78	11.03	11.04	9.68	1.37	1.02	1.09	4.6
	3.73	.134	10	12.57	11.72	12.57	10.94	1.63	.95	.02	5.47
	3.98	.134	10	13.35	12.51	14.19	12.45	1.73	.9	.96	5.82
	4.23	.134	10	14.14	13.29	15.9	14.07	1.84	.85	.9	6.17
	4.48	.134	10	14.92	14.08	17.72	15.78	1.94	.8	.85	6.53
	4.7	.148	9	15.71	14.78	19.63	17.38	2.26	.76	.81	7.58
	4.95	.148	9	16.49	15.56	21.65	19.27	2.37	.73	.77	7.97
	5.2	.148	9	17.28	16.35	23.76	21.27	2.49	.7	.73	8.36
	5.67	.165	8	18.85	17.81	28.27	25.25	3.02	.64	.67	10.16
	6.67	.165	8	21.99	20.95	38.48	34.94	3.54	.55	.57	11.9
	7.67	.165	8	25.13	24.1	50.27	46.2	4.06	.48	.50	13.65
	8.64	.18	7	28.27	27.14	63.62	58.63	4.99	.42	.44	16.76
	9.59	.203	6	31.42	30.14	78.54	72.29	6.25	.38	.4	20.99
	10.56	.22	5	34.56	33.17	95.03	87.58	7.45	.35	.36	25.03
	11.54	.229	4.5	37.7	36.26	113.1	104.63	8.47	.32	.33	28.46
	12.52	.238	4	40.84	39.34	132.73	123.19	9.54	.29	.3	32.06
	13.5	.248	3.5	43.98	42.42	153.94	143.22	10.71	.27	.28	36
	14.48	.259	3	47.12	45.5	176.71	164.72	11.99	.25	.26	40.3
	15.43	.284	2	50.26	48.48	201.06	187.04	14.02	.24	.25	47.11

E 1.—For diameters from 16 up to and including 24 ins. O D. details conformance with the circumstances, as there is not a ss varying.

In *estimating effective* heating or evaporating surfa *liquids by steam,* superheating steam, or transferrin *one gas to another,* mean surface of Tubes is to be

Weight of Seamless Drawn Copper Tubes

American Tube Works. (*Boston.*)

BY EXTERNAL DIAMETER. ONE FOOT IN LENGTH.

Stubs' W. G. From .25 Inch to 12 Ins.—f full, l light.

No.	20	19	18	17	16	15	14	13	12
Ins.	1/32 *f*	3/64 *l*	3/64 *f*	1/16 *l*	1/16 *f*	5/64 *l*	5/64 *f*	3/32 *f*	7/64
Diamet'r.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
.25	.09	.1	.12	.13	.14	.15	.17	.18	.19
.375	.14	.16	.19	.23	.24	.26	.29	.32	.35
.5	.2	.23	.27	.31	.34	.37	.42	.47	.52
.625	.25	.29	.34	.4	.44	.48	.55	.61	.69
.75	.3	.36	.42	.49	.54	.59	.67	.76	.85
.875	.36	.42	.49	.58	.64	.7	.8	.9	1.02
1	.41	.48	.57	.67	.74	.81	.93	1.05	1.18
1.125	.46	.55	.64	.76	.83	.92	1.05	1.19	1.35
1.25	.52	.61	.71	.84	.93	1.03	1.18	1.34	1.52
1.375	.57	.68	.79	.93	1.03	1.14	1.31	1.48	1.68
1.5	.62	.74	.86	1.02	1.13	1.25	1.43	1.63	1.85
1.625	.68	.8	.94	1.11	1.23	1.36	1.56	1.77	2.02
1.75	.73	.87	1.01	1.2	1.33	1.47	1.69	1.92	2.18
1.875	.78	.93	1.09	1.29	1.43	1.58	1.81	2.06	2.35
2	.84	1	1.16	1.37	1.53	1.69	1.94	2.21	2.51
2.125	.89	1.06	1.24	1.46	1.63	1.8	2.07	2.35	2.68
2.25	.94	1.13	1.31	1.55	1.73	1.91	2.19	2.5	2.85
2.375	1	1.19	1.39	1.64	1.82	2.02	2.32	2.64	3.01
2.5	1.05	1.25	1.46	1.73	1.92	2.13	2.45	2.79	3.18
2.625	1.1	1.32	1.54	1.82	2.02	2.23	2.57	2.93	3.35
2.75	1.16	1.38	1.61	1.9	2.12	2.34	2.7	3.08	3.51
2.875	1.21	1.45	1.68	1.99	2.22	2.45	2.83	3.22	3.68
3	1.26	1.51	1.76	2.08	2.32	2.56	2.95	3.37	3.84
3.25	1.37	1.64	1.91	2.26	2.52	2.78	3.21	3.66	4.18
3.5	1.48	1.77	2.06	2.43	2.72	3	3.46	3.95	4.51
3.75	1.58	1.9	2.21	2.61	2.92	3.22	3.71	4.24	4.84
4	1.69	2.02	2.36	2.79	3.11	3.44	3.97	4.53	5.17
4.25	1.8	2.15	2.51	3.14	3.31	3.66	4.22	4.82	5.51
4.5	1.9	2.28	2.65	3.32	3.51	3.88	4.47	5.11	5.84
4.75	2.01	2.41	2.8	3.49	3.71	4.1	4.73	5.4	6.17
5	2.12	2.54	2.95	3.67	3.91	4.32	4.98	5.69	6.5
5.25	2.23	2.66	3.1	3.85	4.11	4.54	5.23	5.98	6.84
5.5	2.34	2.79	3.25	3.85	4.3	4.76	5.49	6.27	7.17
5.75	2.44	2.92	3.4	4.02	4.5	4.98	5.74	6.56	7.5
6	2.55	3.05	3.55	4.2	4.7	5.2	5.99	6.85	7.83
6.25	2.66	3.18	3.7	4.38	4.9	5.41	6.25	7.14	8.17
6.5	2.76	3.31	3.85	4.55	5.1	5.63	6.5	7.43	8.5
6.75	2.87	3.44	4	4.73	5.3	5.85	6.75	7.72	8.83
7	2.98	3.56	4.15	4.91	5.49	6.07	7.01	8.01	9.16
7.25	3.09	3.69	4.3	5.09	5.69	6.29	7.26	8.30	9.5
7.5	3.19	3.82	4.45	5.26	5.89	6.51	7.51	8.59	9.83
8	3.41	4.08	4.74	5.62	6.29	6.95	8.02	9.17	10.49
8.[illegible]	[illegible]	4.33	5.04	5.97	6.68	7.39	8.52	9.75	11.16
[illegible]	[illegible]	4.59	5.34	6.33	7.08	7.83	9.03	10.33	11.82
[illegible]	[illegible]	[illegible]	5.64	6.68	7.48	8.26	9.54	10.91	12.49
[illegible]	[illegible]	[illegible]	[illegible]	7.03	7.87	8.7	10.05	11.49	13.15
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.27	9.14	10.55	12.07	13.82
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.67	9.58	11.06	12.65	14.48
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.02	11.56	13.23	15.15
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.45	12.07	13.81	15.81

o.	10	9	8	7	6	5	4	3	2	1
s.	9/64 l	9/64 f	11/64 l	3/16 l	13/64	7/32 f	15/64 f	1/4 f	9/32 f	19/64 f
et'r.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
75	.4	.41	.42	.44	—	—	—	—	—	—
	.61	.64	.67	.71	.73	.75	.76	—	—	—
25	.81	.86	.92	.99	1.04	1.09	1.12	1.13	1.18	—
5	1.01	1.09	1.17	1.26	1.35	1.42	1.49	1.53	1.61	1.63
75	1.22	1.31	1.42	1.53	1.66	1.76	1.85	1.92	2.04	2.09
	1.42	1.54	1.67	1.81	1.97	2.09	2.21	2.32	2.48	2.55
25	1.63	1.78	1.93	2.08	2.28	2.43	2.58	2.71	2.91	3
5	1.83	2	2.18	2.36	2.59	2.76	2.94	3.11	3.34	3.46
75	2.03	2.22	2.43	2.63	2.9	3.1	3.3	3.5	3.77	3.92
	2.24	2.44	2.68	2.91	3.21	3.43	3.67	3.9	4.21	4.38
25	2.44	2.67	2.93	3.18	3.52	3.77	4.03	4.29	4.64	4.83
5	2.65	2.89	3.18	3.45	3.83	4.11	4.39	4.69	5.07	5.29
5	2.85	3.12	3.44	3.73	4.14	4.44	4.76	5.08	5.51	5.75
	3.06	3.34	3.69	4	4.45	4.78	5.12	5.48	5.94	6.21
5	3.26	3.57	3.94	4.28	4.75	5.11	5.48	5.87	6.37	6.66
	3.46	3.8	4.19	4.55	5.06	5.45	5.84	6.27	6.81	7.12
5	3.67	4.02	4.44	4.82	5.37	5.78	6.21	6.66	7.24	7.57
	3.87	4.25	4.69	5.1	5.68	6.12	6.57	7.06	7.67	8.04
5	4.08	4.47	4.95	5.37	6	6.45	6.93	7.45	8.1	8.49
	4.28	4.7	5.2	5.65	6.3	6.79	7.29	7.85	8.54	8.95
5	4.48	4.92	5.45	5.92	6.61	7.12	7.66	8.24	8.97	9.41
	4.69	5.15	5.7	6.2	6.92	7.46	8.02	8.64	9.4	9.87
	5.1	5.6	6.2	6.74	7.54	8.13	8.75	9.43	10.27	10.78
	5.51	6.05	6.71	7.29	8.16	8.8	9.47	10.22	11.14	11.7
	5.91	6.5	7.21	7.84	8.78	9.47	10.2	11.01	12	12.61
	6.32	6.95	7.71	8.39	9.4	10.14	10.92	11.8	12.87	13.53
	6.73	7.4	8.22	8.94	10.02	10.81	11.65	12.59	13.73	14.44
	7.14	7.85	8.72	9.49	10.64	11.48	12.37	13.38	14.6	15.36
	7.55	8.3	9.22	10.04	11.26	12.16	13.1	14.17	15.46	16.27
	7.96	8.75	9.73	10.58	11.88	12.83	13.83	14.96	16.33	17.19
	8.36	9.21	10.23	11.13	12.49	13.5	14.55	15.75	17.2	18.1
	8.77	9.66	10.73	11.68	13.11	14.17	15.28	16.54	18.06	19.02
	9.18	10.11	11.24	12.23	13.73	14.84	16	17.33	18.93	19.93
	9.59	10.56	11.74	12.78	14.35	15.51	16.73	18.12	19.79	20.85
	10	11.01	12.24	13.33	14.97	16.18	17.46	18.91	20.66	21.76
	10.41	11.46	12.75	13.88	15.59	16.85	18.18	19.7	21.53	22.68
	10.82	11.91	13.25	14.42	16.21	17.52	18.91	20.49	22.39	23.59
	11.22	12.36	13.75	14.97	16.83	18.19	19.63	21.28	23.26	24.51
	11.63	12.81	14.26	15.52	17.45	18.86	20.36	22.07	24.13	25.42
	12.04	13.26	14.76	16.07	18.07	19.54	21.08	22.86	25	26.34
	12.45	13.71	15.26	16.62	18.68	20.21	21.81	23.65	25.86	27.25
	12.86	14.17	15.77	17.17	19.3	20.88	22.54	24.44	26.72	28.17
	13.27	14.62	16.27	17.71	19.92	21.55	23.26	25.23	27.59	29.08
	13.67	15.07	16.77	18.26	20.54	22.22	23.99	26.02	28.45	30
	14.08	15.52	17.28	18.81	21.16	22.89	24.71	26.81	29.32	30.91
	14.49	15.97	17.78	19.36	21.78	23.56	25.44	27.6	30.18	31.83
	14.9	16.42	18.28	19.91	22.4	24.23	26.17	28.39	31.05	32.74
	15.31	16.87	18.79	20.46	23.02	24.9	26.89	29.18	31.92	33.66
	15.72	17.32	19.29	21.01	23.64	25.57	27.62	29.97	[illegible]	34.57
	16.12	17.77	19.79	21.55	24.26	26.24	28.34	30.7		
	16.94	18.68	20.8	22.65	25.5	27.59	29.79	32.		
	17.76	19.58	21.81	23.75	26.73	28.93	31.25	33		
	18.57	20.48	22.81	24.84	27.97	30.27	32.7	35		
	19.39	21.38	23.82	25.94	29.21	31.61	34.15	3		

By Internal Diameter.

Add following Units to Weights for External Diameter in preceding table

No.	1	2	3	4	5	6	7	8	9	10
	2.21	1.97	1.66	1.38	1.18	1.01	.78	.67	.53	.43
No.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	.35	.29	.22	.17	.13	.11	.08	.06	.05	.03

ILLUSTRATION.—What is weight of a copper tube 6 ins. in internal diameter No. 3 gauge, and one foot in length?

By preceding table 6 ins. external, No. 3 gauge = 18.12, and 18.12 + 1.66 = 19.78 *lbs.*

WEIGHT OF BRASS TUBES.

To Compute Weight of Brass Tubes.

American Tube Works. (*Boston.*)

RULE.—Deduct 5 per cent. from weight of Copper tubes.

EXAMPLE.—What is weight of a brass tube 6 ins. in external diameter, No. 3 gauge, and one foot in length?

By preceding table 6 ins. = 18.12, from which deduct 5 per cent. = 17.21 lbs.

By Internal Diameter.

RULE.—Proceed as above for internal diameter, and deduct 5 per cent.

EXAMPLE.—Weight of a copper tube 6 ins. internal diameter, No. 3 gauge, and 1 foot in length = 19.78 *lbs.*

Hence, 19.78 — 5 per cent. = 18.79 *lbs.*

NOTE.—Diameter of Tubes, as for Boilers, is given externally, and that for Pipes internally.

Weights of English are essentially alike to the preceding. (*D. K. Clark.*)

Seamless Brass Pipes.

Made to Correspond with Iron Pipes and to Fit Iron Pipe Fittings.

American Tube Works. (*Boston.*)

WEIGHT PER LINEAL FOOT.

Diameter of Iron Pipe. Internal.	Diameter of Iron Pipe. External.	Weight.	Diameter of Iron Pipe. Internal.	Diameter of Iron Pipe. External.	Weight.	Diameter of Iron Pipe. Internal.	Diameter of Iron Pipe. External.	Weight.
Inch.	Ins.	Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.
.125	.375	.25	1	1.3135	1.7	3	3.5	8.3
.25	.5625	.43	1.25	1.625	2.5	3.5	4	10.9
.375	.6875	.63	1.5	1.875	3	4	4.5	12.7
.5	.8125	.9	2	2.375	4.125	5	5.5625	15.7
.75	1.0625	1.25	2.5	2.875	5.75	6	6.625	20.6

Seamless Copper pipes of like diameter are one nineteenth heavier.

Weight of Sheet Brass.

ONE SQUARE FOOT. (*Holtzapffel's Gauge.*)

Thickness. No.	Thickness. Inch.	Weight. Lbs.	Thickness. No.	Thickness. Inch.	Weight. Lbs.	Thickness. No.	Thickness. Inch.	Weight. Lbs.	Thickness. No.	Thickness. Inch	Weight. Lbs
3	.259	10.9	9	.148	6.23	15	.072	3.03	21	.032	1.35
[illegible]	.238	10	10	.134	5.64	16	.065	2.74	22	.028	1.18
[illegible]	[illegible]	9.26	11	.12	5.05	17	.058	2.44	23	.025	1.05
[illegible]	[illegible]	8.55	12	.109	4.59	18	.049	2.06	24	.022	[illegible]
[illegible]	[illegible]	7.58	13	.095	4	19	.042	1.77	25	.02	[illegible]
[illegible]	[illegible]	6.95	14	.083	3.49	20	.035	1.47			

Weight of Wrought Iron Tubes. (*English.*)

EXTERNAL DIAMETER. ONE FOOT IN LENGTH.

Holtzapffel's Wire-Gauge. f full, l light.

o.	—	—	4	5	6	7	8	9
ns.	.3125 5/16	.281 9/32	.238 15/64 f	.22 7/32	.203 13/64	.18 3/16 l	.165 11/64 l	.148 9/64 f
am.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
7	21.9	19.8	16.9	15.6	14.5	12.9	11.8	10.6
7.5	23.5	21.3	18.1	16.8	15.5	13.8	12.7	11.4
8	25.2	22.7	19.3	17.9	16.6	14.7	13.5	12.2
8.5	26.8	24.2	20.6	19.1	17.6	15.7	14.4	12.9
9	28.4	25.7	21.8	20.2	18.7	16.6	15.3	13.7
9.5	30.1	27.1	23.1	21.4	19.8	17.6	16.1	14.5
0	31.7	28.6	24.3	22.5	20.8	18.5	17	15.3

o.	7	8	9	10	11	12	13	14	15
s.	.18 3/16 l	.165 11/64 l	.148 9/64 f	.134 9/64 l	.12 1/8 l	.109 7/64	.095 3/32 f	.083 5/64 f	.072 5/64 l
m.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
	1.55	1.44	1.32	1.22	1.11	1.02	.9	.797	.7
25	1.78	1.66	1.51	1.39	1.26	1.16	1.3	.906	.794
5	2.02	1.88	1.71	1.57	1.42	1.3	1.15	1.01	.888
75	2.25	2.09	1.9	1.74	1.58	1.45	1.27	1.12	.983
	2.49	2.31	2.1	1.92	1.73	1.59	1.4	1.23	1.08
25	2.72	2.52	2.29	2.09	1.89	1.73	1.52	1.34	1.17
5	2.96	2.74	2.48	2.27	2.05	1.87	1.65	1.45	1.27
75	3.19	2.96	2.68	2.45	2.21	2.02	1.77	1.56	1.36
	3.43	3.17	2.87	2.62	2.36	2.16	1.9	1.67	1.45
25	3.67	3.39	3.06	2.8	2.52	2.3	2.02	1.78	1.55
	3.9	3.6	3.26	2.97	2.68	2.44	2.14	1.88	1.64
5	4.14	3.82	3.45	3.15	2.83	2.59	2.27	1.99	1.74
	4.37	4.04	3.65	3.32	2.99	2.73	2.39	2.1	1.83
5	4.61	4.25	3.84	3.5	3.15	2.87	2.52	2.21	1.93
	4.84	4.47	4.03	3.67	3.31	3.02	2.64	2.32	2.02
5	5.08	4.68	4.23	3.85	3.46	3.16	2.77	2.43	2.11
	5.32	4.9	4.42	4.02	3.62	3.3	2.89	2.54	2.21
	5.79	5.33	4.81	4.37	3.94	3.59	3.14	2.75	2.4
	6.26	5.76	5.2	4.72	4.25	3.87	3.39	2.97	2.59
	6.73	6.19	5.58	5.07	4.57	4.16	3.64	3.19	2.77
	7.2	6.63	5.97	5.43	4.88	4.44	3.89	3.4	2.96
	7.67	7.06	6.36	5.78	5.2	4.73	4.13	3.62	3.15
	8.14	7.49	6.45	6.13	5.51	5.01	4.38	3.84	3.34
	8.61	7.91	7.13	6.48	5.82	5.3	4.63	4.06	3.53
	9.08	8.35	7.52	6.83	6.13	5.58	4.88	4.27	3.72
	9.56	8.79	7.91	7.18	6.44	5.87	5.13	4.49	3.9
	10	9.22	8.3	7.53	6.76	6.15	5.38	4.71	4.09
	10.5	9.65	8.68	7.88	7.07	6.44	5.63	4.93	4.28
	11	10.1	9.07	8.23	7.39	6.73	5.87	5.14	4.47
	11.4	10.5	9.46	8.58	7.7	7.01	6.12	5.36	4.66
	11.9	10.9	9.85	8.93	8.02	7.3	6.37	5.58	4.85
	12.4	11.4	10.2	9.28	8.33	7.58	6.62	5.79	5.03
	12.9	11.8	10.6	9.63	8.64	7.87	6.87	[illegible]	5.22
	13.3	12.2	11	9.99	8.96	8.15	7.12		
	13.8	12.7	11.4	10.3	9.27	8.44	7.3		
	14.3	13.1	11.8	10.7	9.59	8.72	7.6		
	14.7	13.5	12.2	11	9.9	9.01	7.8		

Weight of Seamless Drawn Copper Tubes. (English)

For Diameters and Thicknesses not given in preceding Tables. (*D. K. Clark.*)

INTERNAL DIAMETER. ONE FOOT IN LENGTH.

Holtzapffel's Wire-Gauge. f full, l light.

Specific Weight = 1.16. Wrought Iron = 1.

No.	0000	000	00	0	No.	0000	000	00	0
Ins.	.454 29/64	.425 27/64 f	.38 3/8 f	.34 11/32	Ins.	.454 29/64	.425 27/64 f	.38 3/8 f	.34 11/32
Diam.	Lbs.	Lbs.	Lbs.	Lbs.	Diam.	Lbs.	Lbs.	Lbs.	Lbs.
.75	—	—	—	4.5	5.75	34.2	31.9	28.3	25.2
.875	—	—	5.79	5.02	6	35.6	33.2	29.5	26.2
1	8.02	7.36	6.37	5.53	6.5	38.4	35.8	31.8	28.3
1.125	8.71	8	6.95	6.05	7	41.1	38.3	34.1	30.3
1.25	9.4	8.65	7.52	6.57	7.5	43.9	40.9	36.4	32.4
1.375	10.1	9.3	8.1	7.08	8	46.6	43.5	38.7	34.5
1.5	10.8	9.94	8.68	7.6	9	52.1	48.7	43.3	38.6
1.625	11.5	10.6	9.26	8.12	10	57.7	53.8	47.9	42.7
1.75	12.1	11.2	9.83	8.63	11	63.2	59	52.5	46.8
1.875	12.8	11.9	10.4	9.15	12	68.7	64.2	57.2	51
2	13.5	12.5	11	9.66	13	74.2	69.3	61.8	55.1
2.125	14.2	13.3	11.6	10.2	14	79.7	74.5	66.4	59.2
2.25	14.9	13.8	12.1	10.7	15	85.2	79.6	71	63.4
2.375	15.6	14.5	12.7	11.2	16	90.7	84.8	75.6	67.7
2.5	16.3	15.1	13.3	11.7	17	96.3	90	80.2	71.8
2.625	17	15.8	13.9	12.2	18	101.8	95.1	84.9	76
2.75	17.7	16.4	14.5	12.8	19	107.3	100.3	89.5	80.1
3	19.1	17.7	15.6	13.8	20	112.8	105.5	94.1	84.2
3.25	20.4	19	16.8	14.8	21	118.3	110.7	98.7	88.3
3.5	21.8	20.3	17.9	15.9	22	123.8	115.8	103.3	92.5
3.75	23.2	21.6	19.1	16.9	23	129.3	120.9	107.9	96.6
4	24.6	22.9	20.2	17.9	24	134.8	126.1	112.6	100.6
4.25	25.9	24.2	21.4	19	26	146	136.4	121.8	108.8
4.5	27.3	25.4	22.5	20	28	157.2	146.7	131	117.1
4.75	28.7	26.7	23.7	21	30	168.4	157.1	140.2	125.4
5	30.1	28	24.8	22.1	32	179.6	167.4	149.5	133.6
5.25	31.5	29.3	26	23.1	34	190.7	177.7	158.7	141.9
5.5	32.8	30.6	27.1	24.1	36	201.9	188	167.9	150.1

For Diameters from 13 to 24 Inches.

No.	1	2	3	4	5	6	7	8	9	10
Ins.	.3 19/64 f	.284 9/32 f	.259 1/4 f	.238 15/64 f	.22 7/32 f	.203 13/64	.18 3/16 l	.165 11/64 l	.148 9/64 f	.134 9/64 l
Diam.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
13	48.5	45.8	41.7	38.3	35.3	32.6	28.8	26.4	23.6	21.4
14	52.1	49.3	44.9	41.2	38	35.1	31	28.4	25.4	23
15	55.8	52.7	48	44.1	40.7	37.6	33.2	30.4	27.2	24.6
16	59.4	56.2	51.2	46.9	43.4	40	35.4	32.4	29	26.3
17	63	59.6	54.3	49.8	46	42.5	37.5	34.4	30.8	27.9
18	66.7	63.1	57.4	52.7	48.7	45	39.7	36.4	32.6	29.5
19	70.3	66.5	60.6	55.6	51.4	47.4	41.9	38.4	34.4	31.2
20	74	70	63.7	58.5	54	49.9	44.1	40.4	36.2	32.8
21	77.6	73.4	66.9	61.4	56.7	52.4	46.3	42.4	38	34.4
	[illegible]	76.9	70	64.3	59.4	54.9	48.5	44.4	39.8	36
		80.3	73.2	67.2	62.1	57.3	50.7	46.4	41.6	37.7
		83.8	76.3	70.1	64.7	59.8	52.9	48.5	43.4	39

For Diameters from 13 to 24 Inches.

11	12	13	14	15	16	17	18	19	20
.12	.109	.095	.083	.072	.065	.058	.049	.042	.035
1/8 *l*	7/64	3/32 *f*	5/64 *f*	5/64 *l*	1/16 *f*	1/16 *l*	3/64 *f*	3/64 *l*	1/32 *f*
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
19.1	17.4	15.1	13.2	11.4	10.3	9.2	7.77	6.65	5.55
20.6	18.7	16.3	14.2	12.3	11.1	9.9	8.37	7.16	5.98
22.1	20	17.4	15.2	13.2	11.9	10.6	8.96	7.67	6.4
23.5	21.3	18.6	16.2	14.1	12.7	11.3	9.56	8.18	6.82
25	22.7	19.7	17.2	14.9	13.5	12.1	10.2	8.69	7.27
26.4	24	20.9	18.2	15.8	14.3	12.7	10.7	9.2	7.69
27.9	25.3	22	19.2	16.7	15.1	13.4	11.3	9.71	8.12
29.3	26.6	23.2	20.2	17.6	15.9	14.1	11.9	10.2	8.54
30.8	27.9	24.3	21.3	18.4	16.6	14.8	12.5	10.7	8.96
32.3	29.3	25.5	22.3	19.3	17.4	15.5	13.1	11.2	9.39
33.7	30.6	26.7	23.3	20.2	18.2	16.2	13.7	11.8	9.81
35.2	31.9	27.8	24.3	21.1	19	16.9	14.3	12.3	10.2

Weight of Wrought Iron Tubes. (*English.*)

***Diameters and Thicknesses not given in preceding Tables.* (*D. K. Clark.*)**

INTERNAL DIAMETER. ONE FOOT IN LENGTH.

Holtzapffel's Wire-Gauge. f full, l light.

Thickness in Inches.							4	5	6	7
							.238	.22	.203	.18
5/8	9/16	1/2	7/16	3/8	5/16	1/4	15/64 *f*	7/32 *f*	13/64	3/16 *l*
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
128.5	115.2	102.1	89.1	76.1	63.2	50.4	48	44.2	40.8	36.2
135	121.1	107.3	93.6	80	66.5	53	50.4	46.5	42.9	38
141.5	127	112.6	98.2	83.9	69.7	55.6	52.9	48.8	45.1	39.9
148.1	132.9	117.8	102.8	87.9	73	58.3	55.4	51.1	47.2	41.8
154.6	138.8	123.1	107.4	91.8	76.3	60.9	57.9	53.4	49.3	43.7
161.2	144.7	128.3	112	95.7	79.6	63.5	60.4	55.7	51.5	45.6
174.3	156.5	138.8	121.1	103.6	86.1	68.7	65.4	60.3	55.7	49.3
187.4	168.3	149.2	130.3	111.4	92.7	74	70.4	64.9	60	53.1
200.4	180	159.7	139.5	119.3	99.2	79.2	75.4	69.5	64.2	56.8
213.5	191.8	170.2	148.6	127.1	105.7	84.4	80.4	74.1	68.5	60.6
226.6	203.6	180.6	157.8	135	112.3	89.7	85.4	78.7	72.8	64.4
239.7	215.4	191.1	167	142.9	118.8	94.9	90.4	83.4	77	68.1

8	9	10	11	12	13	14	15	16	17	18
.165	.148	.134	.12	.109	.095	.083	.072	.065	.058	.049
11/64 *l*	9/64 *f*	9/64 *l*	1/8 *l*	7/64	3/32 *f*	5/64 *f*	5/64 *l*	1/16 *f*	1/16 *l*	3/64 *f*
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
33.1	29.7	26.9	24	21.8	19	16.6	14.4	13	11.6	9.78
34.8	31.2	28.3	25.3	22.9	20	17.5	15.1	13.7	12.2	10.3
36.6	32.8	29.7	26.5	24.1	21	18.3	15.9	14.3	12.8	10.8
38.3	34.3	31.1	27.8	25.2	22	19.2	16.6	15	13.4	11.3
40	35.9	32.5	29.1	26.4	23	20.1	17.4	15.7	14	11.8
41.8	37.4	33.9	30.3	27.5	24	20.9	18.1	16.4	14.6	12.6
45.2	40.5	36.7	32.8	29.8	26	22.6	19.7		[illegible]3	13.4
48.7	43.6	39.5	35.3	32.1	28	24.4	21.2			[illegible]4.4
52.1	46.7	42.3	37.8	34.4	30	26.1	22.7			
55.5	49.8	45.1	40.4	36.7	32	27.9	24.[illegible]			
59	52.9	48	42.9	39	34	29.7	25.[illegible]			
[illegible]2.4	56	50.8	45.4	41.3	36	31.4	27.[illegible]			

Weight of a Square Foot of Wrought and (Iron, Steel, Copper, Lead, Brass, and Zinc Plat

From .0625 to 1 Inch in Thickness.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Lead.	Brass.	Gun-metal.	
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
.0625	2.517	2.346	2.541	2.89	3.691	2.675	2.848	
.125	5.035	4.693	5.081	5.781	7.382	5.35	5.696	
.1875	7.552	7.039	7.622	8.672	11.074	8.025	8.545	
.25	10.07	9.386	10.163	11.562	14.765	10.7	11.393	
.3125	12.588	11.733	12.703	14.453	18.456	13.375	14.241	1
.375	15.106	14.079	15.244	17.344	22.148	16.05	17.089	1
.4375	17.623	16.426	17.785	20.234	25.839	18.725	19.938	1
.5	20.141	18.773	20.326	23.125	29.53	21.4	22.786	1
.5625	22.659	21.119	22.866	26.016	33.222	24.075	25.634	2
.625	25.176	23.466	25.407	28.906	36.913	26.75	28.483	2
.6875	27.694	25.812	27.948	31.797	40.604	29.425	31.331	2
.75	30.211	28.159	30.488	34.688	44.296	32.1	34.179	2
.8125	32.729	30.505	33.029	37.578	47.987	34.775	37.027	3
.875	35.247	32.852	35.57	40.469	51.678	36.656	39.875	3
.9375	37.764	35.199	38.11	43.359	55.37	39.331	42.723	3
1	40.282	37.545	40.651	46.25	59.061	42.8	45.572	3

From One Twentieth Inch to Two Inches in Thickness.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Lead.	Brass.	Gun-metal.	
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
.05	2.014	1.877	2.033	2.312	2.593	2.14	2.279	
.1	4.028	3.754	4.065	4.625	5.906	4.28	4.557	
.15	6.042	5.632	6.098	6.938	8.859	6.42	6.836	
.2	8.056	7.509	8.13	9.25	11.812	8.56	9.114	
.25	10.071	9.386	10.163	11.562	14.765	10.7	11.393	
.3	12.085	11.264	12.195	13.875	17.718	12.84	13.672	1
.35	14.099	13.141	14.228	16.187	20.671	14.98	15.95	1
.4	16.113	15.018	16.26	18.5	23.624	17.12	18.229	1
.45	18.127	16.895	18.293	20.812	26.577	19.26	20.507	1
.5	20.141	18.773	20.325	23.125	29.53	21.4	22.786	1
.55	22.155	20.65	22.358	25.437	32.484	23.54	25.065	2
.6	24.169	22.527	24.391	27.75	35.437	25.68	27.343	2
.65	26.183	24.409	26.423	30.063	38.39	27.82	29.622	2
.7	28.197	26.281	28.456	32.375	41.343	29.96	31.9	2
.75	30.211	28.154	30.488	34.687	44.296	32.1	34.179	2
.8	32.226	30.035	32.521	37	47.249	34.24	36.458	2
.85	34.24	31.912	34.553	39.312	50.202	36.38	38.736	3
.9	36.254	33.79	36.586	41.625	53.154	38.52	41.015	3
.95	38.268	35.668	38.628	43.937	56.108	40.66	43.293	3
1	40.282	37.545	40.651	46.25	59.061	42.8	45.572	3
1.125	45.317	42.238	45.732	52.031	66.443	48.15	51.268	4
1.25	50.352	46.931	50.814	57.813	73.826	53.5	56.965	4
	52.87	49.278	53.354	60.703	77.517	56.17	59.813	49
	55.387	51.624	55.895	63.594	81.209	58.85	62.661	51
	57.905	53.971	58.436	66.484	84.9	61.53	65.51	53
	60.422	56.317	60.976	69.375	88.591	64.2	68.358	56
	62.94	58.663	63.517	72.266	92.283	66.88	71.206	58
	[illegible]58	61.011	66.058	75.156	95.974	69.55	74.054	60
		65.704	71.139	80.938	103.356	74.9	79.751	65
		70.397	76.22	86.719	110.739	80.25	85.447	7
		75.09	81.3	92.5	118.122	85.6	91.144	

Standard Cast Iron Water Pipes. (*English.*)

For a Head of 200 Feet.

Thickness.	Depth of Socket.	Thickness of Socket.	Packing.	Weight per Yard.*	Lead Joint.	Diameter.	Thickness.	Depth of Socket.	Thickness of Socket.	Packing.	Weight per Yard.*	Lead Joint.
Inch.	Ins.	Inch.	Inch.	Lbs.	Lbs.	Ins.	Inch.	Ins.	Inch.	Inch.	Lbs.	Lbs.
·3125	3·5	.625	·25	36	.8	8	·4375	3·75	.625	·375	113	3·3
·3125	3	.625	·25	51	1.2	9	·4375	3·75	·75	·375	128	4·6
·375	3	.625	·375	61	2	10	·5	4	·75	·375	168	4·9
·375	3·75	.625	·375	75	2·7	11	·5	4	·75	·375	175	5·3
·375	3·75	.625	·375	85	2·9	12	.5625	4	.875	·375	213	5·7

* Measured as laid.

To Compute Weight of Metal Pipes.

$^2 - d^2$ C. D *and* d *representing external and internal diameters in inches,* C *coefficient.*

ast Iron 2.45. Wrought Iron 2.64. Brass 2.82. Copper 3.03. Lead 3.86.

Compute Weight of Metal Tubes and Pipes per Lineal Foot.

From .5 Inch to 6 Inches Internal Diameter.

ι.	Area of Plate.	Diam.	Area of Plate.	Diam.	Area of Plate.	Diam.	Area of Plate.
	Sq. Foot.	Ins.	Sq. Foot.	Ins.	Sq. Feet.	Ins.	Sq. Feet.
	.1309	1.3125	.3436	2.75	.7199	4.5	1.1781
:5	.1473	1.375	.36	2.875	.7526	4.625	1.2108
	.1636	1.4375	.3764	3	.7854	4.75	1.2435
5	.18	1.5	.3927	3.125	.8181	4 875	1.2763
	.1964	1.625	.4254	3.25	.8508	5	1.309
5	.2127	1.75	.4581	3.375	.8836	5.125	1.3417
	.2291	1.875	.4909	3.5	.9163	5.25	1.3744
5	.2454	2	.5236	3.625	.949	5.375	1.4072
	.2618	2.125	.5543	3.75	.9818	5.5	1.4399
5	.2782	2.25	.587	4	1.0472	5.625	1.4726
	.2945	2.375	.6198	4.125	1.0799	5.75	1.5053
;	.3105	2.5	.6545	4.25	1.1126	5.875	1.5381
	.3272	2.625	.6872	4.375	1.1454	6	1.5708

Application of Table.

When Thickness of Metal is given in Divisions of an Inch.

internal diameter of tube or pipe add thickness of metal; take of the plate in square feet, from table for a diameter equal to of diameter and thickness of tube or pipe, and multiply it by of a square foot of metal for given thickness (see table, page and again by its length in feet.

STRATION.—Required weight of 10 feet of copper tube 1 inch in diameter and an inch in thickness.

: + .125 = 1.125 × 3.1416 ÷ 12 = .2945 *square feet for 1 foot of le*

ht of 1 square foot of copper .125th of an inch in thickness, 5.781 *lbs.;* then, .2945 (from table above) × 5.781 × 10 = 17.02

en Thickness of Metal is given in Numbers of a Wire

nternal diameter of tube or pipe add thickness of *p. 120 or 121; multiply* sum by 3.1416, divide produ *it will give area of plate* in square feet. Then procee

ILLUSTRATION.—Required weight of 10 feet of copper pipe 2 inches in d and No. 2 American wire-gauge in thickness.

$2 + .25763 \times 3.1416 \div 12 = 2.25763 \times 3.1416 \div 12 = .591$ *square feet;* th $\times$ 11.6706 (weight from table, page 118) = 6.897 *lbs.*

Weight of Riveted Iron and Copper Pip

From 5 to 30 Inches in Diameter.

ONE FOOT IN LENGTH.

Diameter.	Thickness.	Iron.	Copper.	Diameter.	Thickness.	Iron.
Ins.	Inch.	Lbs.	Lbs.	Ins.	Inch.	Lbs.
5	.125	7.12	8.14	9	.25	25.01
	.1875	10.68	12.21		.25	26.33
	.25	14.25	16.28	10	.25	27.75
5.5	.125	7.78	8.89	10.5	.25	29.19
	.1875	11.66	13.33	11	.25	30.49
	.25	15.56	17.78	12	.25	33.13
6	.125	8.44	9.64	13	.25	35.88
	.1875	12.65	14.46	14	.25	38.52
	.25	16.88	19.29	15	.25	41.26
6.5	.125	9.1	10.4		.3125	51.57
	.1875	13.65	15.6	16	.25	43.9
	.25	18.2	20.8		.3125	54.87
7	.125	9.78	11.18	17	.25	46.53
	.1875	14.68	16.78		.3125	58.17
	.25	19.57	22.37	18	.25	49.17
7.5	.125	10.49	11.99		.3125	61.47
	.1875	15.73	17.98	20	.3125	68.07
	.25	20.89	23.87	24	.3125	81.33
8	.1875	16.7	19.08	25	.3125	84.57
	.25	22.26	25.44	28	.3125	94.56
8.5	.25	23.59	26.96	30	.3125	101.14

Above weights include laps of sheets for riveting and calking.

Weights of the rivets are not added, as number per lineal foot of pipe upon the distance they are placed apart, and their diameter and length upon thickness of metal of the pipe.

Weight of Copper Rods or Bolts,

From .125 Inch to 4 Inches in Diameter.

ONE FOOT IN LENGTH.

Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.	W
Inch.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	
.125	.047	.8125	1.998	1.5	6.811	2.75	2
.1875	.106	.875	2.318	.5625	7.39	.875	2
.25	.189	.9375	2.66	.625	7.993	3	2
.3125	.296	1	3.03	.75	9.27	.125	2
.375	.426	1.0625	3.42	.875	10.642	.25	3
.4375	.579	.125	3.831	2	12.108	.375	3
.5	.757	.1875	4.269	.125	13.668	.5	3
.5625	.958	.25	4.723	.25	15.325	.625	3
625	1.182	.3125	5.21	.375	17.075	.75	4
75	1.431	.375	5.723	.5	18.916	.875	4
	1.703	.4375	6.255	.625	20.856	4	

Weight of Metals of a Given Sectional Area.

From .1 Square Inch to 10 Square Inches.

PER LINEAL FOOT. (*D. K. Clark.*)

Wrought Iron. 1.	Cast Iron. .9375.	Steel. 1.02.	Brass. 1.052.	Gun-metal. 1.092.	Sect. Area.	Wrought Iron. 1.	Cast Iron. .9375.	Steel. 1.02.	Brass. 1.052.	Gun-metal. 1.092.
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Sq. Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
.33	.31	.34	.35	.36	5.1	17	15.9	17.3	17.9	18.6
.67	.62	.68	.7	.73	5.2	17.3	16.3	17.7	18.2	18.9
1	.94	1.02	1.05	1.09	5.3	17.7	16.6	18	18.6	19.3
1.33	1.25	1.36	1.43	1.46	5.4	18	16.9	18.4	18.9	19.7
1.67	1.56	1.7	1.75	1.82	5.5	18.3	17.2	18.7	19.3	20
2	1.88	2.04	2.11	2.18	5.6	18.7	17.5	19	19.6	20.4
2.33	2.19	2.38	2.46	2.55	5.7	19	17.8	19.4	20	20.8
2.67	2.5	2.72	2.81	2.91	5.8	19.3	18.1	19.7	20.3	21.1
3	2.81	3.06	3.16	3.28	5.9	19.7	18.4	20.1	20.7	21.5
3.33	3.15	3.4	3.51	3.64	6	20	18.8	20.4	21	21.8
3.67	3.44	3.74	3.86	4	6.1	20.3	19.1	20.7	21.4	22.2
4	3.75	4.08	4.21	4.37	6.2	20.7	19.4	21.1	21.7	22.6
4.33	4.06	4.42	4.56	4.73	6.3	21	19.7	21.4	22.1	22.9
4.67	4.38	4.76	4.91	5.1	6.4	21.3	20	21.8	22.4	23.3
5	4.69	5.1	5.26	5.46	6.5	21.7	20.3	22.1	22.8	23.7
5.33	5	5.44	5.61	5.82	6.6	22	20.6	22.4	23.1	24
5.67	5.31	5.78	5.96	6.19	6.7	22.3	20.9	22.8	23.5	24.4
6	5.63	6.12	6.31	6.55	6.8	22.7	21.3	23.1	23.9	24.8
6.33	5.94	6.46	6.66	6.92	6.9	23	21.6	23.5	24.2	25.1
6.67	6.25	6.8	7.01	7.28	7	23.3	21.9	23.8	24.6	25.5
7	6.56	7.14	7.36	7.64	7.1	23.7	22.2	24.1	24.9	25.8
7.33	6.88	7.48	7.72	8.01	7.2	24	22.5	24.5	25.3	26.2
7.67	7.19	7.82	8.07	8.37	7.3	24.3	22.8	24.8	25.6	26.6
8	7.5	8.16	8.42	8.74	7.4	24.7	23.1	25.2	26	26.9
8.33	7.81	8.5	8.77	9.1	7.5	25	23.4	25.5	26.3	27.3
8.67	8.13	8.84	9.12	9.46	7.6	25.3	23.8	25.9	26.7	27.7
9	8.44	9.18	9.47	9.83	7.7	25.7	24.1	26.2	27	28
9.33	8.75	9.52	9.82	10.2	7.8	26	24.4	26.5	27.4	28.4
9.67	9.06	9.86	10.2	10.6	7.9	26.3	24.7	26.9	27.7	28.8
10	9.38	10.2	10.5	10.9	8	26.7	25	27.2	28.1	29.1
10.3	9.69	10.5	10.9	11.3	8.1	27	25.3	27.5	28.4	29.5
10.7	10	10.9	11.2	11.7	8.2	27.3	25.6	27.9	28.8	29.9
11	10.3	11.2	11.6	12	8.3	27.7	25.9	28.2	29.1	30.2
11.3	10.6	11.6	11.9	12.4	8.4	28	26.3	28.6	29.5	30.6
11.7	10.9	11.9	12.3	12.7	8.5	28.3	26.6	28.9	29.8	30.9
12	11.3	12.2	12.6	13.1	8.6	28.7	26.9	29.2	30.2	31.3
12.3	11.6	12.6	13	13.5	8.7	29	27.2	29.6	30.5	31.7
12.7	11.9	12.9	13.3	13.8	8.8	29.3	27.5	29.9	30.9	32
13	12.2	13.3	13.7	14.2	8.9	29.7	27.8	30.3	31.2	32.4
13.3	12.5	13.6	14	14.6	9	30	28.1	30.6	31.6	32.8
13.7	12.8	13.9	14.4	14.9	9.1	30.3	28.4	30.9	31.9	33.1
14	13.1	14.3	14.7	15.3	9.2	30.7	28.8	31.3	32.3	33.5
14.3	13.4	14.6	15.1	15.7	9.3	31	29.1	31.6	32.6	33.9
14.7	13.8	15	15.4	16	9.4	31.3	29.4	32	33	34.2
15	14.1	15.3	15.8	16.4	9.5	31.7	29.7	[illegible]	[illegible]	34.6
15.3	14.4	15.6	16.1	16.7	9.6	32	30			[illegible]
15.7	14.7	16	16.5	17.1	9.7	32.3	30.3			
16	15	16.3	16.8	17.5	9.8	32.7	[illegible]			
16.3	15.3	16.7	17.2	17.8	9.9	33	[illegible]			
16.7	15.6	17	17.5	18.2	10	33.3	[illegible]			

N*

Weight of Lead Pipe. (*English.*)

ONE FOOT IN LENGTH.

Diam.	Thickness.	Weight.	Diam.	Thickness.	Weight.	Diam.	Thickness.	Weight.	Diam.	Thickness.
Inch.	Inch.	Lbs.	Ins.	Inch.	Lbs.	Ins.	Inch.	Lbs.	Ins.	Inch.
.5	.097	.93	1	.136	2.4	1.75	.166	5	3	.275
	.112	1.07		.156	2.8		.199	6	3.5	.225
	.124	1.2		.2	3.73		.228	7		.273
	.146	1.47		.225	4.27		.256	8	4	.257
.625	.089	1	1.25	.139	3	2	.178	6		.3125
	.101	1.13		.16	3.5		.204	7		.327
	.121	1.4		.18	4		.231	8	4.25	.3125
	.14	2		.193	4.33		.266	9.33	4.5	.232
.75	.112	1.6	1.5	.156	4	2.5	.2	8.4		.295
	.147	1.87		.179	4.67		.227	9.6		.3125
	.181	2.13		.224	6		.261	11.2	4.75	.3125
	.215	2.4		.257	7	3	.218	11.2	5	.3125

Dimensions of Copper Pipes and Composit Cocks.

From 1 Inch to 23 Inches in Diameter.

Diam. of Pipe and Cock.	Flange Diameter. Pipe.	Flange Diameter. Cock.	Thickness.	Bolts. No.	Bolts. Diam.	Diam. of Pipe and Cock.	Flange Diam. Pipe.	Thickness.	B No.
Ins.	Ins.	Ins.	Inch.		Inch.	Ins.	Ins.	Inch.	
1	3.375	3.5	.375	3	.5	9	12.75	.625	9
1.25	3.625	3.75	.375	3	.5	9.25	13.125	.625	10
1.5	3.875	4.25	.375	3	.5	9.5	13.375	.6875	10
1.75	4.125	4.375	.4375	4	.5	9.75	13.625	.6875	10
2	4.375	4.75	.4375	4	.5	10	13.875	.6875	10
2.25	4.625	5.25	.4375	5	.5	10.5	14.5	.6875	10
2.5	4.875	5.5	.4375	5	.5	11	15	.6875	10
2.75	5.25	5.75	.4375	5	.5	11.5	15.625	.75	10
3	6	6.25	.5	5	.625	12	16.125	.75	10
3.25	6.125	6.625	.5	6	.625	12.5	16.625	.75	10
3.5	6.375	6.875	.5	6	.625	13	17.25	.75	10
3.75	6.625	7.25	.5	6	.625	13.5	17.875	.75	10
4	6.875	7.375	.5	6	.625	14	18.375	.75	10
4.25	7.125	7.625	.5	6	.625	14.5	18.875	.75	10
4.5	7.375	8.25	.5	6	.625	15	19.5	.75	10
4.75	7.625	8.5	.5	6	.625	15.5	20	.75	10
5	8	9	.5	6	.625	16	20.5	.75	10
5.25	8.25	9.25	.5	6	.625	16.5	21.125	.75	10
5.5	8.5	9.5	.5	6	.625	17	21.625	.75	11
5.75	9	9.875	.5	6	.625	17.5	22.125	.75	11
6	9.25		.625	8	.625	18	22.75	.75	11
6.25	9.75		.625	8	.625	18.5	23.25	.75	11
6.5	10		.625	8	.625	19	23.75	.75	12
6.75	10		.625	8	.625	19.5	24.375	.75	12
7	10.5		.625	8	.625	20	24.875	.75	12
7.25	10.75		.625	8	.625	20.5	25.375	.75	13
	25		.625	8	.625	21	26	.75	13
	5		.625	8	.625	21.5	26.5	.75	13
	5		.625	9	.625	22	27	.75	13
			.625	9	.625	22.5	27.625	.75	14
			.625	9	.625	23	28.125	.75	14
			.625	9	.625				

Weight of Sheet Lead.

PER SQUARE FOOT.

[Thi]ckness.	Weight.	Thickness.	Weight.	Thickness.	Weight.	Thickness.	Weight.
[I]nch.	Lbs.	Inch.	Lbs.	Inch.	Lbs.	Inch.	Lbs.
[.0]17	1	.068	4	.118	7	.169	10
[.0]34	2	.085	5	.135	8	.186	11
[.0]51	3	.101	6	.152	9	.203	12

Weight of Tin Pipe.

ONE FOOT IN LENGTH.

[Dia]m. [Intern]al.	THICKNESS. 3/32 inch.	THICKNESS. 1/8 inch.	Diam. External.	THICKNESS. 3/32 inch.	THICKNESS. 1/8 inch.	Diam. External.	THICKN. 1/4 inch.	Diam. External.	THICKN. 1/4 inch.
.	Lb.	Lbs.	Ins.	Lbs.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
;	.148	—	1.25	1.095	1.417	2.25	5.04	3.25	7.56
	.384	.472	1.5	1.328	1.732	2.5	5.67	3.5	8.19
	.62	.787	1.75	1.564	2.047	2.75	6.3	3.75	8.82
	.856	1.103	2	1.802	2.362	3	6.93	4	9.45

Weight of Lead Encased Tin Pipes.

[Diamet]er.	Light Weights.			For Supply of Water Head.* 50 feet and under.	For Supply of Water Head.* 51 to 250 feet.	For Supply of Water Head.* 251 to 500 feet.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
5	1	1.5	2	2.5 to 4	3 to 4.5	3.5 to 5
	2	2.5	3	3.5 " 5	4 " 6	4.5 " 7
5	3	3.5	4	4.5 " 7	5.25 " 8	6 " 9
	3.5	4	4.5	5.5 " 8	6 " 9	7 " 10
	4.5	5	5.5	7.25 " 10	8 " 11	9 " 12
	6.5	7	8	9 " 12.5	10 " 14	12 " 16
	8	9	10	11 " 16	12.5 " 18	14 " 21
	11	13	—	16 " 23	18.5 " 26	21 " 30

* The extreme weights are for extra heavy pipe with less proportion of tin.

[Dim]ensions and Weight of Sheet Zinc. (*Vielle-Montagne.*)

PER SQUARE FOOT.

Thickness.		2×.5 metres; area, 1 square metre. 6.56×1.64 feet; area, 10.76 square feet.		2×.65 metres; area, 1.3 sq. metres. 6.56×2.13 feet; area, 13.99 square feet.		2×.8 metres; area, 1.6 sq. metres. 6 56×2.62 ft.; area, 17.22 square feet.		Weight.
[Mi]llim.	Inch.	Kilom.	Lbs.	Kilom.	Lbs.	Kilom.	Lbs.	Lbs.
.41	.0161	2.9	6.39	3.7	8.16	4.6	10.14	.589
.51	.0201	3.45	7.61	4.45	9.81	5.5	12.12	.704
6	.0236	4.05	8.93	5.3	11.68	6.5	14.33	.832
69	.0272	4.65	10.25	6.1	13.45	7.5	16.53	.96
78	.0307	5.3	11.68	6.9	15.21	8.5	18.74	1.088
87	.0343	5.95	13.12	7.7	16.94	9.5	20.94	1.216
96	.0378	6.55	14.44	8.55	18.85	10.5	23.15	1.344
1	.0433	7.5	16.53	9.75	21.5	12	26.46	1.536
23	.0485	8.45	18.63	10.95	24.14	13.5	29.97	1.74
36	.0536	9.35	20.61	12.2	26.9	15	33.07	1.92
48	.0583	10.3	22.71	13.4	29.54	16.5	36.38	2.112
66	.0654	11.25	24.8	14.6	32.19	18	39.[illegible]	[illegible]204
85	.0729	12.5	27.56	16.25	35.82	20	4[illegible]	[illegible]
02	.0795	13.75	30.31	17.9	39.46	22	4[illegible]	[illegible]
9	.0862	15	33.07	19.5	42.99	24	[illegible]	[illegible]
7	.0933	16.25	35.82	21.1	46.52	26	[illegible]	[illegible]
2	.0992	17.5	38.58	22.75	50.15	28	[illegible]	[illegible]
6	.1047	18.8	41.44	24.4	53.79	31	[illegible]	[illegible]

Table—(*Continued*).

Special Sizes for Sheathing Ships.

No.	Thickness.		*Dimensions of Sheets.* 1.15 × .35 metres; area, .402 sq. metre. 3.77 × 1.15 feet; area, 4.33 sq. feet.		1.3 × .4 metres; area, .52 sq. metre. 4.26 × 1.31 feet; area, 5.6 sq. feet.		Weight per Sq. Feet.
	Millim.	Inch.	Kilom.	Lbs.	Kilom.	Lbs	Lbs.
15	.96	.0378	2.65	5.84	3.4	7.5	1.344
16	1.1	.0433	3	6.61	3.9	8.6	1.536
17	1.23	.0485	3.4	7.5	4.4	9.7	1.74
18	1.36	.0536	3.75	8.27	4.9	10.8	1.92
19	1.48	.0583	4.15	9.15	5.35	11.79	2.112
20	1.66	.0654	4.55	10.03	5.85	12.9	2.304

NOTE.—A deviation of 25 dekagrammes, or about half a pound, more or less, from the proper weight of each number of sheet, is allowed.

Nos. 1 to 9 are employed for perforated articles, as sieves, and for *articles de Paris*. Nos. 10 to 12 are used in manufacture of lamps, lanterns, and tin-ware generally, and for stamped ornaments. The last numbers are used for lining reservoirs, and for baths and pumps.

Ship and Railroad Spikes.

DIMENSIONS AND NUMBER PER POUND. (*F. C. Page, Mass.*)

Ship Spikes.

¼ In. Sq.		5/16 In. Sq.		7/16 In. Sq.		½ In. Sq.		9/16 In. Sq.		⅝ In. Sq.		¾ In. Sq.	
Length.	No. in Pound.	Length.	No. in Pound.	Length.	No. in Pound.	Length.	No. in Pound.	Length.	No. in Pound.	Length.	No. in Pound.	Length.	No. in Pound.
Ins.		Ins.		Ins.		Ins.		Ins.		Ins.		Ins.	
3	19	3	10	4	5.4	5	3.4	6	2.2	8	1.4	10	.8
3.5	15.8	3.5	9.6	4.5	5	5.5	3.1	6.5	2	9	1.2	15	.6
4	13.2	4	8	5	4.6	6	3	7	1.9	10	1.1	—	—
4.5	12.2	4.5	6	5.5	4.2	6.5	2.8	7.5	1.8	11	1	—	—
5	10.2	5	5.8	6	4	7	2.6	8	1.7	—	—	—	—
—	—	6	5.2	6.5	3.2	7.5	2.4	8.5	1.6	—	—	—	—
—	—	—	—	—	—	8	2.2	9	1.5	—	—	—	—
—	—	—	—	—	—	—	—	10	1.4	—	—	—	—

Railroad Spikes . . . . . .5 inch square × 5.5 ins. 2 per lb.
" " . . . . . .5625 " " × 5.5 " 1.6 "

Spikes and Horseshoes.

LENGTH AND NUMBER PER POUND. (*H. Burden, Troy, N. Y.*)

Boat Spikes.				Ship Spikes.				Hook Head.		Horseshoes.	
Length.	No. in Lb.	Length.	No. in Lb.	Length.	No. in Lb.	Length.	No. in Lb.	Length.	No. in Lb.	Length.	No. in Lb.
Ins.		Ins.		Ins.		Ins.		Ins.		Ins.	
3	17.5	6.5	4.78	4	8	7.5	2.5	4 × .375	5.55	1	.8
3.5	14.68	7	3.62	4.5	6.5	8	1.74	4.5 × .4375	4.14	2	.7
4	12.57	7.5	3.37	5	4.37	8.5	1.63	5 × .5	2.52	3	.6
[illegible]	[illegible]	8	2.95	5.5	4.3	9	1.55	5.5 × .5	2.41	4	.5
		8.5	2.9	6	4.2	10	1.15	5.5 × .5625	1.87	5	.3
		9	2.1	6.5	3.77	—	—	6 × .5625	1.72	-	-
		0	1.98	7	2.75	—	—	6 × .625	1.38	-	-

ght and Volume of Cast Iron and Lead Balls.

From 1 Inch to 20 Inches in Diameter.

r.	Volume.	Cast Iron.	Lead.	Diameter.	Volume.	Cast Iron.	Lead.
	Cube Ins.	Lbs.	Lbs.	Ins.	Cube Ins.	Lbs.	Lbs.
	.523	.136	.215	9	381.703	99.51	156.553
	1.767	.461	.725	9.5	448.92	117.034	184.121
	4.189	1.092	1.718	10	523.599	136.502	214.749
	8.181	2.133	3.355	10.5	606.132	158.043	248.587
	14.137	3.685	5.798	11	696.91	181.765	285.832
	22.449	5.852	9.207	11.5	796.33	207.635	326.591
	33.51	8.736	13.744	12	904.778	235.876	371.096
	47.713	12.439	19.569	12.5	1022.656	266.647	419.512
	65 45	17.063	26.843	13	1150.346	299.623	471.806
	87.114	22.721	35.729	14	1436.754	374.563	589.273
	113.097	29.484	46.385	15	1767.145	460.696	724.781
	143.793	37.453	58.976	16	2144.66	559.114	879.616
	179.594	46.82	73.659	17	2572.44	670.717	1055.066
	220.893	57.587	90.598	18	3053.627	796.082	1252.422
	268.082	69.889	109.952	19	3591.363	936.271	1472.97
	321.555	83.84	131.883	20	4188.79	1092.02	1717.995

E.—To compute weight of balls of other metals, multiply weight given in y following multipliers:

Wrought Iron............ 1.067. | Brass........................ 1.12.
eel...................... 1.088. | Gun-metal.................. 1.165.

Weight and Diameter of Cast Iron Balls.

Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.
Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.
1.94	12	4.45	50	7.16	224	11.8	1344	21.44
2.45	14	4.68	56	7.43	336	13.51	1568	22.57
2.8	16	4.89	60	7.6	448	14.87	1792	23.6
3.08	18	5.09	70	8.01	560	16.02	2016	24.54
3.32	20	5.27	80	8.37	672	17.02	2240	25.42
3.53	25	5.68	90	8.71	784	17.91	2800	27.38
3.72	28	5.9	100	9.02	896	18.73	3360	29.1
3.89	30	6.04	112	9.37	1008	19.48	3920	30.64
4.04	40	6.64	168	10.72	1120	20.17	4480	32.03

Length of Horseshoe Nails.

By Numbers.

...... 1.5 Ins.	No. 7....... 1.875 Ins.	No. 9........ 2.25 Ins.
..... 1.75 "	" 8...... 2 "	" 10........ 2.5 "

gths of Iron Nails, and Number in a

.	No.	Size.	L'gth.	No.	Size.	L'gth.	No.	Size.	L'gth.	No.	Size
			Ins.			Ins.			Ins.		
	420	5d.	1.75	220	8d.	2.5	100	12d.	3.25	52	30
	270	6	2	175	10	3	65	20	3.5	28	40

Wrought Iron Cut Nails, Tacks, Spike

(Cumberland Nail and Iron Co.)

Lengths and Number per Lb.

Ordinary.

Size.	Length.	No. per Lb.
	Ins.	
2d	.875	716
3 fine	1.0625	588
3	1.0625	448
4	1.375	336
5	1.75	216
6	2	166
7	2.25	118
8	2.5	94
10	2.75	72
12	3.5	50
20	3.75	32
30	4.25	20
40	4.75	17
50	5	14
60	5.5	10

Light.

4d	1.375	373
5	1.75	272
6	2	196

Brads.

6d	2	163
8	2.5	96
10	2.75	74
12	3.125	50

Fence.

6d	2	96
7	2.25	66
8	2.5	56
10	2.75	50
—	3	40

Finishing.

Size.	Length.	No. per Lb.
	Ins.	
4d	1.375	384
5	1.75	256
6	2	204
8	2.5	102
10	3	80
12	3.625	65
20	3.875	46

Core.

6d	2	143
8	2.5	68
10	2.333	60
12	3.125	42
20	3.75	25
30	4.25	18
40	4.75	14
WH	2.5	69
WHL	2.25	72

Clinch.

6d	2	152
7	2.25	133
8	2.5	92
10	2.75	72
—	3	60
—	3.25	43

Slate.

3d	1.625	288
4	1.4375	244
5	1.75	187
6	2	146

Shin

Size.	Lengtl
	Ins.
5d	1.75
8	2.5
9	2.75
10	3

Tac

1 oz.	.125
1.5	.187
2	.25
2.5	.312
3	.375
4	.437
6	.562
8	.625
10	.687
12	.75
14	.812
16	.875
18	.937
20	1

Bo

Size.
Ins.
1.5

Spil

3.5
4
4.5
5
5.5
6

Railroad Spikes.

Number in a Keg of 150 lbs.

Length.	No.	Length.	No.	Length.	No.	Len
No.		Ins.		Ins.		In
3 × .375	930	3.5 × .4375	675	4 × .5	450	5 ×
3.5 × .375	890	4 × .4375	540	4.5 × .5	400	5.5 ×
4 × .375	760	4.5 × .4375	510	5 × .5	340	

5.5 × .5625 standard for a gauge of 4 feet 8.5 ins.

Ship and Boat Spikes.

Number in a Keg of 150 lbs.

Length.	No.	Length.	No.	Length.	No.	Leng
Ins.		Ins.		Ins.		In
4 × .25	1650	5 × .3125	930	8 × .375	455	10 × .
4.5 × .25	1464	6 × .3125	868	9 × .375	424	8 × .
5 × .25	1380	7 × .3125	662	10 × .375	390	9 × .
6 × .25	1292	6 × .375	570	8 × .4375	384	10 ×
7 × .25	1161	7 × .375	482	9 × .4375	300	11

Weight of Various Metals.

Per Cube Inch and Foot.

[TAL]S.	Spec. Gravity.	W'ght in an Inch.	Ins. in a Lb.	Weight in a Foot.	METALS.	Specific Gravity.	W'ght in an Inch.	Ins. in a Lb.	Weight in a Foot.
[Wrou]ght-iron		Lb.		Lbs.			Lb.		Lb.
plates	7734	.2797	3.57	483.38	Brass, rolled.	8 217	.2972	3.37	513.6
wire.	7774	.2812	3.55	485.87	" cast...	8 080	.2922	3.42	505
[I]ron....	7209	.2607	3.84	450.54	Lead, rolled.	11 340	.4101	2.44	708.73
plates..	7804	.2823	3.54	487.8	Tin, cast.....	7 292	.2673	3.74	462
wire...	7847	.2838	3.52	490.45	Zinc, rolled..	7 188	.26	3.85	449.28
[...]r, {...	8697	.3146	3.19	543.6	Aluminium, cast	2 560	.0926	10.8	160
[...]ed {...	8880	.3212	3.11	555					
[...]metal, }	8750	.3165	3.16	546.875	Silver.......	10 480	.3791	2.64	655
......}					Tobin Bronze.	8 379	.3031	3.299	523.69

English. (*D. K. Clark.*)

[Wrou]ght iron	7.698	.278	3.6	480	Tin.........	7.409	.268	3.74	462
[I]ron....	7.217	.26	3.84	450	Zinc........	7.008	.253	3.95	437
....	7.852	.283	3.53	489.6	Lead........	11.418	.412	2.43	712
[...]r plates	8.805	.318	3.15	549	Brass, cast...	8.099	.292	3.42	505
[...]etal...	8.404	.304	2.02	524	" wire..	8.548	.308	3.24	533

WROUGHT AND CAST IRON.

[T]o Compute Weight of Wrought or Cast Iron.

[RUL]E.—Ascertain number of cube inches in piece; multiply sum by .2816* for [wroug]ht iron and .2607* for cast, and product will give weight in pounds.

[F]or cast iron multiply weight of pattern, if of pine, by from 18 to 20, accord[ing to] its degree of dryness.

[EXA]MPLE.—What is weight of a cube of wrought iron 10 inches square by 15 [inches] in length?

$$10 \times 10 \times 15 \times .2816 = 422.4 \text{ lbs.}$$

COPPER.

To Compute Weight of Copper.

[RULE]:.—Ascertain number of cube inches in piece; multiply sum by .32118,* [and pr]oduct will give weight in pounds.

Sheathing and Braziers' Sheets.

[For d]imensions and weights see Measures and Weights, pages 118–121, 131, 142.

LEAD.

To Compute Weight of Lead.

[RULE.]—Ascertain number of cube inches in piece; multiply sum by .41015,* [and pro]duct will give weight in pounds.

[EXAM]PLE.—What is weight of a leaden pipe 12 feet long, 3.75 inches in diameter, [... in]ch thick?

[By R]ule in *Mensuration of Surfaces, to ascertain Area of Cylindrical Rings.*

Area of $(3.75 + 1 + 1) = 25.967$
" " $3.75 \quad = 11.044$
Difference, 14.923 (*area of ring*) × 144 (12 feet) = 2148.9
[...]; = 881.376 *lbs.*

BRASS.

[To] Compute Weight of Ordinary Bras[s Cas]tings.

[RULE.]—Ascertain number of cube inches in piece; multi[ply ...] .* and [product w]ill give weight in pounds.

* [Weigh]ts of a cube inch as here given are for the ordinary metals [... when] the metal under consideration is accurately known, the weig[ht ...] [us]ed for the units here given.

Dimensions and Weights of Wrought Iron Bolts and Nuts.

SQUARE AND HEXAGONAL HEADS AND NUTS.

Rough, *and from* .25 *Inch to* 4 *Inches in Diameter.*

Square Head and Nut.

Diameter of Bolt.	Width. Head.	Width. Nut.	Diagonal. Head.	Diagonal. Nut.	Depth. Head.	Depth. Nut.	Weight. Head and Nut.	Weight. Bolt per Inch.	Threads per Inch.
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Lbs.	Lbs.	No.
.25	.36	.49	.51	.69	.25	.25	.024	.014	20
.3125	.45	.58	.64	.82	.3	.3125	.043	.022	18
.375	.54	.67	.76	.95	.34	.375	.068	.031	16
.4375	.63	.76	.89	1.07	.4	.4375	.104	.042	14
.5	.72	.84	1.02	1.19	.44	.5	.145	.055	13
.5625	.82	.94	1.16	1.33	.48	.5625	.204	.07	12
.625	.91	1.03	1.29	1.46	.53	.625	.273	.086	11
.6875	1	1.12	1.41	1.58	.58	.6875	.356	.104	11
.75	1.09	1.21	1.54	1.71	.63	.75	.454	.124	10
.8125	1.18	1.3	1.67	1.84	.67	.8125	.565	.145	10
.875	1.27	1.39	1.8	1.96	.72	.875	.696	.168	9
1	1.45	1.57	2.05	2.22	.81	1	1.013	.22	8
1.125	1.63	1.75	2.3	2.47	.9	1.125	1.416	.278	7
1.25	1.81	1.94	2.56	2.74	1	1.25	1.923	.344	7
1.375	1.99	2.12	2.81	3	1.1	1.375	2.543	.416	6
1.5	2.17	2.3	3.07	3.25	1.18	1.5	3.234	.495	6
1.625	2.36	2.48	3.34	3.51	1.28	1.625	4.105	.581	5.5
1.75	2.54	2.66	3.59	3.76	1.37	1.75	5.087	.674	5
1.875	2.72	2.84	3.85	4.02	1.46	1.875	6.182	.773	5
2	2.9	3.02	4.1	4.27	1.56	2	7.491	.88	4.5
2.125	3.08	3.21	4.35	4.54	1.65	2.125	8.936	.993	4.5
2.25	3.26	3.39	4.61	4.79	1.75	2.25	10.543	1.113	4.5
2.375	3.44	3.57	4.86	5.05	1.84	2.375	12.335	1.24	4.375
2.5	3.62	3.75	5.12	5.3	1.94	2.5	14.359	1.375	4.25
2.625	3.81	3.93	5.49	5.56	2.03	2.625	16.549	1.515	4
2.75	3.99	4.11	5.64	5.81	2.12	2.75	18.897	1.663	4
2.875	4.17	4.29	5.9	6.07	2.22	2.875	21.545	1.818	3.75
3	4.35	4.47	6.15	6.32	2.31	3	24.464	1.979	3.5
3.25	4.71	4.84	6.66	6.84	2.5	3.25	30.922	2.323	3.5
3.5	5.07	5.2	7.17	7.35	2.68	3.5	38.391	2.694	3.25
3.75	5.44	5.56	7.69	7.86	2.87	3.75	47.168	3.093	3
4	5.8	5.92	8.2	8.37	3.06	4	56.882	3.518	3

FINISHED.—Deduct .0625 from diameters of bolts and depths of all heads and nuts.

Screws with square threads have but one half number of threads of those with triangular threads.

NOTE.—The loss of tensile strength of a bolt by cutting of thread is, for one of 1.25 ins. diameter, 8 per cent. The safe stress or capacity of a wrought iron bolt and nut may be taken at 5000 lbs. per square inch.

Preceding width, depth, etc., are for work to exact dimensions, whether forged or finished.

To Compute Weight of a Bolt and Nut.

...—Ascertain from table weight of head and nut for given di... , and add thereto weight of bolt per inch of its length, multi... ...ength of its body from inside of its head to end.

...h of a bolt and nut for measurement, as such, is taken from insid... ... of nut, or its greatest capacity when in position.

USTRATION.—A wrought iron bolt and nut with a square head and nut is 1 inch ameter and 10 inches in length; what is its weight?

Weight of head and nut..................1.013 *lbs.*
" bolt per inch of length .22 × 10 = 2.2 "
3.213 "

Hexagonal Head and Nut.

eter olt.	Width. Head.	Width. Nut.	Diagonal. Head.	Diagonal. Nut.	Depth. Head.	Depth. Nut.	Weight. Head and Nut.	Weight. Bolt per Inch.	Threads per Inch.
s.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Lbs.	Lbs.	No.
5	.375	.5	.43	.58	.25	.25	.022	.014	20
125	.4375	.5625	.5	.65	.3	.3125	.037	.022	18
75	.5625	.6875	.65	.79	.34	.375	.062	.031	16
375	.625	.75	.72	.87	.4	.4375	.094	.042	14
	.75	.875	.87	1	.44	.5	.134	.055	13
525	.8125	.9375	.94	1.08	.48	.5625	.18	.07	12
25	.9375	1.0625	1.08	1.23	.53	.625	.249	.086	11
875	1	1.125	1.16	1.3	.58	.6875	.318	.104	11
5	1.125	1.25	1.3	1.44	.63	.75	.413	.124	10
125	1.25	1.375	1.44	1.59	.67	.8125	.522	.145	10
75	1.3125	1.4375	1.52	1.66	.72	.875	.639	.168	9
	1.5	1.625	1.73	1.88	.81	1	.931	.22	8
25	1.6875	1.8125	1.95	2.09	.9	1.125	1.299	.278	7
5	1.875	2	2.17	2.31	1	1.25	1.759	.344	7
75	2	2.1875	2.31	2.53	1.1	1.375	2.263	.416	6
	2.25	2.375	2.6	2.74	1.18	1.5	2.958	.495	6
5	2.4375	2.5625	2.81	2.96	1.28	1.625	3.741	.581	5.5
	2.625	2.75	3.03	3.18	1.37	1.75	4.654	.674	5
5	2.8125	2.9375	3.25	3.39	1.46	1.875	5.675	.773	5
	3	3.125	3.46	3.61	1.56	2	6.854	.88	4.5
5	3.1875	3.3125	3.68	3.83	1.65	2.125	8.163	.993	4.5
	3.375	3.5	3.9	4.04	1.75	2.25	9.658	1.113	4.5
5	3.5625	3.6875	4.11	4.26	1.84	2.375	11.263	1.24	4.375
	3.75	3.875	4.33	4.47	1.94	2.5	13.149	1.375	4.25
5	3.9375	4.0625	4.55	4.69	2.03	2.625	15.15	1.515	4
	4.125	4.25	4.77	4.91	2.12	2.75	17.285	1.663	4
5	4.3125	4.4375	4.99	5.12	2.22	2.875	19.751	1.818	3.75
	4.5	4.625	5.2	5.34	2.31	3	22.378	1.979	3.5
	4.875	5	5.63	5.77	2.5	3.25	28.258	2.323	3.5
	5.25	5.375	6.06	6.21	2.68	3.5	35.081	2.694	3.25
	5.625	5.75	6.5	6.64	2.87	3.75	43.178	3.093	3
	6	6.125	6.93	7.07	3.06	4	51.942	3.518	3

NISHED.—Deduct .0625 from diameters of bolts and depths of all heads nuts.

For Wood or Carpentry.

ad and Nut (*Square*), 1.75 diameter of bolt. *Depth of Head*, .75, *d*, .9.

sher.—Thickness, .35 to .4 of diameter of bolt, on *Pine* 3.5 diame *Dak* 2.5.

English.

lesworth gives following elements of Thread of Bolts:

gle of thread, 55°. *Depth of thread* ≐ Pitch of screw.

mber of threads per Inch.—*Square*, half number of ls.

th of thread.—.64 pitch for angular and .475 for s

O

French Standard Bolts and Nuts. (*Armengaud's.*)

HEXAGONAL HEADS AND NUTS.

Equilateral Triangular Thread.								*Square Thread.*					
Diameter of Bolt.		Diameter at Base of Thread.	Threads per Inch.	Thickness. Head.	Thickness. Nut.	Breadth across Flats.	Safe Tensile Stress.	Diameter of Bolt.		Depth of Thread.	Threads per Inch.	Thickness of Nut.	Safe Tensile Stress.
Mm.	Ins.	Ins.	No.	Ins.	Ins.	Ins.	Lbs.	Mm.	Ins.	Ins.	No.	Ins.	Lbs.
5	.2	.13	18.1	.24	.2	.55	44	20	.79	.072	6.57	1.82	717
7.5	.3	.22	16	.3	.3	.68	99	25	.98	.081	5.97	2.01	1 142
10	.39	.31	14.1	.38	.39	.88	178	30	1.18	.093	5.4	2.22	1 635
12.5	.49	.39	12.7	.44	.49	1.04	277	35	1.38	.1	4.93	2.41	2 218
15	.59	.48	11.5	.52	.59	1.2	400	40	1.57	.106	4.53	2.63	2 912
17.5	.69	.58	10.6	.58	.69	1.4	545	45	1.77	.114	4.2	2.85	3 674
20	.79	.66	9.8	.66	.79	1.5	713	50	1.97	.128	3.91	3.07	4 547
22.5	.89	.76	9.1	.72	.89	1.68	902	55	2.17	.13	3.65	3.3	5 288
25	.98	.84	8.5	.8	.98	1.84	1 120	60	2.36	.14	3.43	3.5	6 540
30	1.18	1.02	7.5	.94	1.18	2.16	1 635	65	2.56	.15	3.23	3.7	7 660
35	1.38	1.2	6.7	1.08	1.38	2.48	2 218	70	2.76	.158	3.06	3.92	8 893
40	1.58	1.4	6	1.22	1.58	2.8	2 912	75	2.95	.166	2.92	4.13	10 214
45	1.77	1.56	5.5	1.36	1.77	3.2	3 674	80	3.15	.174	2.76	4.36	11 603
50	1.97	1.74	5.1	1.5	1.97	3.44	4 547	85	3.35	.183	2.63	4.58	13 100
55	2.17	1.92	4.7	1.64	2.17	3.76	5 288	90	3.54	.192	2.51	4.78	14 794
60	2.36	2.08	4.4	1.74	2.36	4.08	6 540	95	3.74	.2	2.41	5	16 352
65	2.56	2.26	4.1	1.92	2.56	4.4	7 660	100	3.94	.209	2.31	5.22	18 144
70	2.76	2.44	3.8	2.06	2.76	4.7	8 893	105	4.13	.22	2.22	5.43	20 000
75	2.95	2.6	3.5	2.2	2.95	5	10 214	110	4.33	.226	2.13	5.66	21 950
80	3.15	2.78	3.4	2.34	3.15	5.35	11 468	115	4.53	.23	2.06	5.87	23 990

English Bolts and Nuts. (*Whitworth's.*)

Hexagonal Heads and Nuts, and Triangular Threads.

Diameter. Bolt.	Diameter. Base of Thread.	Threads per Inch.	Depth. Head.	Depth. Nut.	Width of Head and Nut.	Diameter. Bolt.	Diameter. Base of Thread.	Threads per Inch.	Depth. Head.	Depth. Nut.	Width of Head and Nut.
Ins	Inch.	No.	Inch.	Ins.	Ins.	Ins.	Ins.	No.	Ins.	Ins.	Ins.
.125	.093	40	.109	.125	.338	1.25	1.067	7	1.094	1.25	2.048
.1875	.134	24	.164	.1875	.448	1.375	1.161	6	1.203	1.375	2.215
.2187	—	24	—	—	—	1.5	1.286	6	1.312	1.5	2.413
.25	.186	20	.219	.25	.525	1.625	1.369	5	1.422	1.625	2.576
.3125	.241	18	.273	.3125	.601	1.75	1.494	5	1.531	1.75	2.758
.375	.295	16	.328	.375	.709	1.875	1.59	4.5	1.641	1.875	3.018
.4375	.346	14	.383	.4375	.82	2	1.715	4.5	1.75	2	3.149
.5	.393	12	.437	.5	.919	2.125	1.84	4.5	1.859	2.125	3.337
.5625	.456	12	.492	.5625	1.011	2.25	1.93	4	1.969	2.25	3.546
.625	.508	[illegible]	.547	.625	1.101	2.375	2.055	4	2.078	2.375	3.75
.6875	.571	[illegible]	.601	.6875	1.201	2.5	2.18	4	2.187	2.5	3.894
.75	.622	10	.656	.75	1.301	2.625	2.305	4	2.297	2.625	4.049
.8125	.684	10	.711	.8125	1.39	2.75	2.384	3.5	2.406	2.75	4.181
[illegible]	[illegible]	9	.766	.875	1.479	2.875	2.509	3.5	2.516	2.875	4.346
[illegible]	[illegible]	[illegible]	.82	.9375	1.574	3	2.634	3.5	2.625	3	4.531
				—	1.67	3.25	2.84	3.25	—	—	—
					.86	3.5	3.06	3.25	—	—	—

Square Heads and Nuts. (*Whitworth's.*)

Diameter.		Threads per Inch.	Diameter.		Threads per Inch.	Diameter.		Threads per Inch.
lt.	Base of Thread.		Bolt.	Base of Thread.		Bolt.	Base of Thread.	
s.	Ins.	No.	Ins.	Ins.	No.	Ins.	Ins.	No.
75	3.25	3	4.5	3.875	2.875	5.25	4.4375	2.625
	3.5	3	4.75	4.0625	2.75	5.5	4.625	2.625
25	3.75	2.875	5	4.25	2.75	6	4.875	2.5

Weight of Heads and Nuts in Lbs. (*Molesworth.*)

'exagonal, 1.07 D^3. *Square,* 1.35 ^{3} D^3. *D representing diameter of bolt ıches.*

tentiveness of Wrought Iron Spikes and Nails.

Deduced from Experiments of Johnson and Bevan.

SPIKES.

Spike.	Wood.	Breadth.	Depth.	Depth of Insertion.	Force required to draw it.	Ratio of force to weight.	Remarks.
		Ins.	Ins.	Ins.	Lbs.		
re......	Hemlock†	.39	.3	3.5	1297	1.58	Seasoned in part.
*....	Chestnut	.37	.38	3.5	1873	2.16	Unseasoned.
*....	Yellow pine	.375	.375	3.375	2052	2.37	Seasoned.
*....	White oak	.375	.375	3.375	3910	4.52	"
......	Locust	.4	.4	3.5	5967	6.33	"
ıarrow..	Chestnut	.39	.25	3.5	2223	3.93	Unseasoned.
"	White oak	.39	.25	3.5	3990	7.05	Seasoned.
"	Locust	.39	.25	3.5	5673	9.32	"
broad..	Chestnut	.539	.288	3.5	2394	2.66	Unseasoned.
"	White oak	.539	.288	3.5	5330	5.71	Seasoned.
"	Locust	.539	.288	3.5	7040	7.84	"
'e Draw filed.	Hemlock†	.4	.39	3.5	1638	1.75	Seasoned in part.
	Chestnut†	.4	.39	3.5	1790	1.81	Unseasoned.
	Locust†	.4	.39	3.5	3990	4.17	Seasoned in part.
l and ıved..	Ash	Diam.	.5	3.5	2052	2.21	Seasoned.
"	"	"	.5	3.5	2451	2.41	"
"	White oak	"	.48	3.5	3876	3.2	"

Burden's patent. † Soaked in water after the spikes were driven.

NAILS.

..	Length.	Depth of Insertion.	Force required to draw it. Pine.	Hemlock.	Elm.	Oak.	Beech.	Pressure required to force them into Pine.
	Ins.	Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
ıny	2	1	187	312	327	507	667	[illegible]
	2	1.5	327	539	571	675	88	
	2	2	530	857	899	1394	18[illegible]	

General Remarks.

ı a given breadth of face, a decrease of depth will
oft woods, a *blunt-pointed* spike forces the fibr
ırds so as to leave the fibres longitudinally in con
spike.

To obtain greatest effect, fibres of the wood should press faces of the spike in direction of their length; thus, a round blunt bolt, driven into a hole of a less diameter, has a retention equal to that of any other form, when wholly driven, as without boring.

The retention of a spike, whether square or flat, in unseasoned chestnut, from two to four inches in length of insertion, is about 800 lbs. per square inch of the two surfaces which laterally compress the faces of the spike.

When wood was soaked in water, after spikes were driven, order of their retentive power was Locust, White oak, Chestnut, Hemlock, and Yellow Pine.

Gas Pipe Threads.

Diameter in Inches..	.125	.25	.375	.5	.75	1	1.25	1.5	1.75	2
Threads per Inch...	28	19	19	14	14	11	11	11	11	11

ANGLES AND DISTANCES.

Angles and Distances corresponding to Opening of a Rule of Two Feet.

Angle.	Distance.	Angle.	Distance.	Angle.	Distance.	Angle.	Distance.	Angle.	Distance.
°	Ins.	°	Ins.	°	Ins.	°	Ins.	°	Ins.
1	.2	19	3.96	37	7.61	55	11.08	73	14.28
2	.42	20	4.17	38	7.81	56	11.27	74	14.44
3	.63	21	4.37	39	8.01	57	11.45	75	14.61
4	.84	22	4.58	40	8.2	58	11.64	76	14.78
5	1.05	23	4.78	41	8.4	59	11.82	77	14.94
6	1.26	24	4.99	42	8.6	60	12	78	15.11
7	1.47	25	5.19	43	8.8	61	12.18	79	15.27
8	1.67	26	5.4	44	8.99	62	12.36	80	15.43
9	1.88	27	5.6	45	9.18	63	12.54	81	15.59
10	2.09	28	5.81	46	9.38	64	12.72	82	15.75
11	2.3	29	6.01	47	9.57	65	12.9	83	15.9
12	2.51	30	6.21	48	9.76	66	13.07	84	16.06
13	2.72	31	6.41	49	9.95	67	13.25	85	16.21
14	2.92	32	6.62	50	10.14	68	13.42	86	16.37
15	3.13	33	6.82	51	10.33	69	13.59	87	16.52
16	3.34	34	7.02	52	10.52	70	13.77	88	16.67
17	3.55	35	7.22	53	10.71	71	13.94	89	16.82
18	3.75	36	7.42	54	10.9	72	14.11	90	16.97

Distances and Angles corresponding to Opening of a Rule of Two Feet.

Distance.	Angle.	Distance.	Angle.	Distance.	Angle.	Distance.	Angle.	Distance.	Angle.	Distance.	Angle.
Ins.	°	Ins.	°	Ins.	°	Ins.	°	Ins.	°	Ins.	°
.25	1.12	3	14.22	6.5	31.26	10	49.14	13.5	68.28		
.375	1.48	3.25	15.34	6.75	32.4	10.25	50.34	13.75	69.54		
.5	2.24	3.5	16.46	7	33.54	10.5	51.54	14	71.22		
.625	2.59	3.75	17.58	7.25	35.09	10.75	53.14	14.25	72.5		
[illegible]	3.35	4	19.11	7.5	36.24	11	54.34	14.5	74.2		
	4.12	4.25	20.24	7.75	37.4	11.25	55.54	14.75	75.5		
	4.48	4.5	21.37	8	38.56	11.5	57.16	15	77.2[illegible]		
	5.58	4.75	22.5	8.25	40.12	11.75	58.38	15.25	78.5		
	[illegible]	5	24.4	8.5	41.28	12	60	15.5	80.[illegible]		
	[illegible]	5.25	25.16	8.75	42.46	12.25	61.23	15.75	[illegible]		
			26.3	9	44.2	12.5	62.46	16	[illegible]		
			[illegible]7.44	9.25	45.2	12.75	64.1	16.25			
			[illegible].58	9.5	46.38	13	65.36	16.5			
			[illegible].12	9.75	47.56	13.25	67.02	16.75			

WIRE ROPE.

Vire rope will run over sheaves of like diameter to *Hemp rope* of same ngth; but larger sheaves reduce wear. Adhesion is the same as that of ıp rope. Wear increases rapidly with speed. Short bends should be ided. In substituting wire rope for hemp, allow same weight per foot. king wire rope materially damages and often destroys it.

or transmission of power, wire rope can be used up to distances of 3 s. For distances less than 100 feet, it is not advised for long trans- ion; sheaves are placed at intervals, dividing it into a number of ter ones of 250 to 300 feet.

rength per square inch of section of rope is about 50 per cent. of an l section of solid metal of same strength per square inch.

ationary wire ropes should be kept well painted or tarred to prevent oxidation. Running ropes should always be well lubricated and pro- d from grit with linseed-oil, pine tar, graphite grease, or any similar cid substances.

ındard wire rope is made of 6 strands of 7, 12, or 19 wires each, with or wire centre. Wire centre adds 10 per cent. to strength and weight e, but reduces its flexibility proportionally.

e working load for standing ropes is about one fourth ultimate strength, r running ropes it is from one fifth to one seventh.

es for hoisting are composed of 6 strands of 19 wires each around a centre.

es for transmission of power, for guys and rigging, are composed of ıds of 7 or 12 wires each.

ultimate strength of wires of which wire ropes are made are for: ire, 70 000 to 90 000 lbs. per sq. inch; Bessemer steel wire, 100 000 to ɔ lbs.; Crucible cast-steel wire, 150 000 to 180 000 lbs., and Special -steel wire, 210 000 to 300 000 lbs.

ial ropes can be made of 4, 6, 8, etc., strands of varied construction. ropes are also made flat, composed of several strands alternately l to right and left, laid alongside each other, and sewed together ft iron wire.

hawsers of steel are made of 6 strands of 12 wires each with hemp around a common hemp centre, and are as flexible as hemp hawsers l strength.

anized wire rope replaces hemp for rigging, because of its cheapne ity, and resistance to stretch. It is one fifth bulk for equal streng p rope, and offers less surface to wind.

ropes for vessel-steering gear are made of 6 small centre, each small rope composed of 6 strands of 7 ntre—252 wires in all in the rope, giving great flexi

rigging of galvanized cast-steel rope is one third to *vire rope of equal strength.*

Elements of Running and Standing Wire Rope.

John A. Roebling's Sons Co., New York.

HOISTING ROPE.

19 *Wires in a Strand. Hemp Centre.*

	Iron.						Cast Steel.			
Diam.	Circum.	Weight per Foot.	Ultimate Strength.	Safe Load .2	Circum. Equivalent to New Hemp Rope.	Min. Size Sheave.	Ultimate Strength.	Safe Load .2	Circum. Equivalent to New Hemp Rope.	Min. Size Sheave.
Ins.	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Ft.	Lbs.	Lbs.	Ins.	Ft.
.375	1.178	.26	5 000	1 000	2.5	1.5	9 000	1 800	3.5	1
.5	1.708	.35	6 960	1 392	3	2.25	14 000	2 800	4.5	1.5
.625	1.964	.6	10 260	2 052	3.75	3.5	24 000	4 800	5.75	2.25
.75	2.256	.88	17 280	3 456	4.75	4	36 000	7 200	7	3
.875	2.749	1.2	23 000	4 600	5.5	4.5	50 000	10 000	8.5	3.5
1	3.142	1.58	32 000	6 400	6.5	5.25	66 000	13 200	9.5	4
1.125	3.534	2	40 000	8 000	7.5	6	84 000	16 800	11	4.5
1.25	3.927	2.5	54 000	10 800	8.5	6.5	104 000	20 800	12	5
1.375	4.32	3	66 000	13 200	9.5	7	126 000	25 200	13	5.5
1.5	4.712	3.65	78 000	15 600	10	7.5	154 000	30 800	14	5.75
1.625	5.105	4.1	88 000	17 600	11	8.5	176 000	35 200	15	6.25
1.75	5.498	5.25	108 000	21 600	12	10	212 000	42 400	—	7.25
2	6.283	6.3	130 000	26 000	13	12	250 000	50 000	—	8
2.25	7.069	8	148 000	29 600	14	13	310 000	62 000	—	8.5

Transmission and Standing Rope.

7 *Wires in a Strand. Hemp Centre.*

	Iron.						Cast Steel.			
Diam.	Circum.	Weight per Foot.	Ultimate Strength.	Safe Load .2	Circum. Equivalent to New Hemp Rope.	Min. Size Sheave.	Ultimate Strength.	Safe Load .2	Circum. Equivalent to New Hemp Rope.	Min. Size Sheave.
Ins.	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Ft.	Lbs.	Lbs.	Ins.	Ft.
.375	1.178	.19	3 300	660	2.25	2.75	8 000	1 600	3.25	2
.5	1.571	.31	5 660	1 132	2.75	4	12 000	2 400	4	2.5
.625	1.964	.57	11 600	2 320	4	5.25	22 000	4 400	5.5	3.5
.75	2.356	.88	17 600	3 520	4.75	6.75	34 000	6 800	7	4.5
.875	2.749	1.12	24 600	4 920	5.75	7.5	44 000	8 800	8	5
1	3.142	1.5	32 000	6 400	6.5	8.5	60 000	12 000	9	5.75
1.125	3.534	1.82	40 000	8 000	7.5	9.5	72 000	14 400	10	6.25
1.25	3.927	2.28	50 000	10 000	8.5	10.75	88 000	17 600	11	7.25
1.375	4.320	2.77	60 000	12 000	9	12	104 000	20 800	12	8
1.5	4.712	3.37	72 000	14 400	10	13	124 000	24 800	13	8.5

Note.—Add 10 per cent. to weight for wire centre.

Galvanized Charcoal Iron Wire Rope.

Vessels' Rigging and Derrick Guys.

7 *or* 12 *Wires in a Strand.*

Circum.	Weight per Fathom.	Ultimate Strength.	Safe Load .25	Circum. Equivalent to New Hemp Rope.	Circum.	Weight per Fathom.	Ultimate Strength.	Safe Load .25	Circum. Equivalent to New Hemp Rope.
	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Lbs.	Lbs.	Lbs.	Ins.
[illegible]	[illegible]	[illegible]	6 000	5.75	4.5	19	60 000	15 000	9
[illegible]	[illegible]	[illegible]	7 000	6	4.75	21	66 000	16 500	9.5
[illegible]	[illegible]	[illegible]	8 000	6.5	5	22	70 000	17 500	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	7.5	5.25	24.5	80 000	[illegible]	[illegible]
					5.5	26.5	86 000	[illegible]	[illegible]
					6	28.5	100 000	[illegible]	[illegible]

ʇalvanized Charcoal Iron Wire Rope.

Vessels' Rigging and Derrick Guys.

John A. Roebling's Sons Co., New York.

7 Wires in a Strand.

'eight per .thom.	Ultimate Strength.	Safe Load .25	Circum. Equivalent to New Hemp Rope.	Circum.	Weight per Fathom.	Ultimate Strength.	Safe Load .25	Circum. Equivalent to New Hemp Rope.
Lbs.	Lbs.	Lbs.	Ins.	Ins.	Lbs.	Lbs.	Lbs.	Ins.
.25	750	187.5	1.125	1.5	2	7000	1750	3
.375	1250	312.5	1.25	1.75	2.5	10000	2500	3.75
.5	1500	375	1.5	2	3.5	14000	3500	4.5
.75	2000	500	1.75	2.25	4.5	16000	4000	4.75
.875	4000	1000	2.25	2.5	5.5	18000	4500	5
.25	4500	1125	2.375	2.75	6.75	20000	5000	5.25
.75	5000	1250	2.5	—	—	—	—	—

Galvanized Steel Hawsers.

For Sea and Lake Towing.

Ultimate Strength.	Circum. equival't to New Hemp Hawser.	Circumference.	Ultimate Strength.	Circum. equival't to New Hemp Hawser.
Lbs.	Ins.	Ins.	Lbs.	Ins.
30000	6.5	3.5	58000	9
36000	7	4	70000	10
44000	8.5	—	—	—

nized Steel Cables for Suspension Bridges.

Ultimate Strength.	Weight per Foot.	Diameter.	Ultimate Strength.	Weight per Foot.	Diameter.	Ultimate Strength.	Weight per Foot.
Lbs.	Lbs.	Ins.	Lbs.	Lbs.	Ins.	Lbs.	Lbs.
130000	3.7	1.875	200000	5.8	2.375	360000	10
150000	4.35	2	220000	6.5	2.5	400000	11.3
190000	5.6	2.25	310000	8.64	2.625	440000	13

uge, Weight, and Length of Iron Wire.

Weight per 100 Feet.	Weight of one Mile.	63 lbs. Bundle.	Area.	Gauge.	Diam.	Weight per 100 Feet.	Weight of one Mile.	63 lbs. Bundle.	Area.
Lbs.	Lbs.	Feet.	Sq. Inch.	No.	Inch.	Lbs.	Lbs.	Feet.	Sq. Inch.
56.1	2962	112	.166 19	16	.063	1.05	55	6000	.003 117
49.01	2588	129	.145 22	17	.054	.77	41	8182	.002 29
40.94	2162	154	.121 304	18	.047	.58	31	10862	.001 734
34.73	1834	181	.102 921	19	.041	.45	24	14000	.001 32
29.04	1533	217	.086 049	20	.035	.32	17	19687	.000 962
27.66	1460	228	.074 023	21	.032	.27	14	23333	.000 804
21.23	1121	296	.062 901	22	.028	.21	11	30000	.000 615
18.34	968	343	.054 325	23	.025	.175	9.24	36000	.000 4[illegible]
15.78	833	399	.046 759	24	.023	.14	7.39	45000	.000[illegible]
13.39	707	470	.039 76	25	.02	.116	6.124	54310	.00[illegible]
11.35	599	555	.033 653	26	.018	.093	4.91	67742	.00[illegible]
9.73	514	647	.028 952	27	.017	.083	4.382	75903	.00[illegible]
8.03	439	759	.024 605	28	.016	.074	3.907	85135	.00[illegible]
6.96	367	905	.020 612	29	.015	.061	3.22	103278	.00[illegible]
5.08	306	1086	.017 203	30	[illegible]		[illegible].851	116666	.00[illegible]
4.83	255	1304	.014 313	31	[illegible]		[illegible]	126000	.00[illegible]
3.82	202	1649	.011 309	32				136956	.000[illegible]
2.92	154	2158	.008 659	33				[illegible]	.000[illegible]
2.24	118	2813	.006 647	34				[illegible]	.000 078
1.69	89	3728	.005 026	35				[illegible]	.000 07[illegible]
1.37	72	4598	.004 071	36					[illegible]

Weight and Strength of Single Strand and Cable laid Fence Wire. (*F. Morton & Co.*)

Strands.	No.	Single Wire of equal Diameter.		Length per 1000 lbs. Of a Strand.	Length per 1000 lbs. Of Rope.	Strands.	No.	Single Wire of equal Diameter.		Length per 1000 lbs. Of a Strand.	Length per 1000 lbs. Of Rope.
No.		No.	Inch.	Feet.	Feet.	No.		No.	Inch.	Feet.	Feet.
3	2A	8	.159	20 090	15 270	7	00	4	.229	8300	7366
4	2	7	.174	14 730	12 790	7	3/0	3	.25	8036	6228
7	1	6	.191	13 125	10 580	7	4/0	2	.274	7500	5156
7	0	5	.209	10 446	8 928	7	5/0	1	.3	5090	4286

No. and diameter of wire is that of Ryland's Bros., pp. 122–4.

Hemp, Iron, and Steel. (*R. S. Newall & Co.*)

ROUND.

HEMP. Circumference.	HEMP. Weight per Foot.	IRON. Circumference.	IRON. Weight per Foot.	STEEL. Circumference.	STEEL. Weight per Foot.	Tensile Strength. Safe Load.	Tensile Strength. Ultimate Strength.
Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.
2.75	.33	1	.16	—	—	672	4 480
		1.5	.25	1	.16	1 008	6 720
3.75	.66	1.625	.33	—	—	1 344	8 960
		1.75	.42	1.5	.25	1 680	11 200
4.5	.83	1.875	.5	—	—	2 016	13 440
		2	.58	1.625	.33	2 352	15 680
5.5	1.16	2.125	.66	1.75	.42	2 688	17 920
		2.25	.75	—	—	3 024	20 160
6	1.5	2.375	.83	1.875	.5	3 360	22 400
		2.5	.92	—	—	3 696	24 640
6.5	1.66	2.625	1	2	.58	4 032	26 680
		2.75	1.08	2.125	.66	4 368	29 120
7	2	2.875	1.16	2.25	.75	4 704	31 360
		3	1.25	—	—	5 040	33 600
7.5	2.33	3.125	1.33	2.375	.83	5 376	36 840
		3.25	1.41	—	—	5 672	38 080
8	2.66	3.375	1.5	2.5	.92	6 048	40 320
		3.5	1.66	2.625	1	6 720	44 800
8.5	3	3.625	1.83	2.75	1.08	7 392	49 280
		3.75	2	—	—	8 064	53 760
9.5	3.66	3.875	2.16	3.25	1.33	8 736	58 240
10	4.33	4	2.33	—	—	9 408	62 720
		4.25	2.5	3.375	1.5	10 080	67 200
11	5	4.375	2.66	—	—	10 752	71 680
		4.5	3	3.5	1.66	12 096	80 640
12	5.66	4.625	3.33	3.75	2	13 440	89 600

FLAT.

HEMP. Dimensions.	HEMP. Weight per Foot.	IRON. Dimensions.	IRON. Weight per Foot.	STEEL. Dimensions.	STEEL. Weight per Foot.	Safe Load.	Ultimate Strength.
4 × .5	3.33	2.25 × .5	1.85	—	—	4 928	44 800
5 × 1.25	4	2.5 × .5	2.16	—	—	5 824	51 520
5.5 × 1.375	4.33	2.75 × .625	2.5	—	—	6 720	60 480
5.75 × 1.5	4.66	3 × .625	2.66	2 × .5	1.66	7 168	62 720
6 × 1.5	5	3.25 × .625	3	2.25 × .5	1.83	8 064	71 680
7 × 1.875	6	3.5 × .625	3.33	2.25 × .5	2	8 960	80 640
8.25 × 2.125	[illegible]	[illegible].75 × .6875	3.66	2.5 × .5	2.16	9 850	89 600
[illegible]		[illegible] × .6875	4.16	2.75 × .375	2.5	11 200	100 800
		[illegible] × .75	4.66	3 × .375	2.66	12 544	112 000
		[illegible] × .75	5.33	3.25 × .375	3	14 336	125 440
		[illegible] × .75	5.66	3.5 × .375	3.23	15 232	134 400

ı preceding tables following results are determined:

	Ultimate Strength per Lb. Weight per Foot.	Safe Load per Lb. Weight per Foot.	Safe Load per Square of Circumference in Inches.
	Lbs.	Lbs.	Lbs.
....	15 000	4550	100
....	22 000	4500	600
....	{ 30 000 45 500	{ 6000 8000	{ 1000 1300

FLAT MINING ROPES.

John A. Roebling's Sons Co., New York.

Thickness.	Weight per Foot.	Safe Load.	Width.	Thickness.	Weight per Foot.	Safe Load.
Ins.	Lbs.	Lbs.	Ins.	Ins.	Lbs.	Lbs.
·375	1.19	63 000	5.5	·375	3.9	156 000
·375	1.86	74 000	5.5	·5	4.8	193 000
·375	2.32	93 000	6	·375	4.34	173 000
·5	2.97	118 000	6	·4375	4.5	160 000
·375	2.86	114 000	6	·5	5.1	210 000
·5	3.3	130 000	6.5	·5	5.5	224 000
·375	3.12	125 000	7	·5	5.9	238 000
·5	4	160 000	7.5	·5	6.25	250 000
·375	3.4	125 000	6	·5	6.75	270 000
·5	4.27	170 000				

Ropes and Chains of Equal Strength.

ter ain.	Circumference. Hemp Rope.	Crucible Steel Rope.	Charcoal Iron Rope.	Weight per Foot. Steel Rope.	Iron Rope.	Hemp Rope.	Iron Chain.	Safe Load.
	Ins.	Ins.	Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Tons.
75	2.75	—	1	—	.14	.34	.5	.3
	3	—	1.18	—	.21	.46	.65	.4
25	3.5	1	1.39	.17	.28	.67	.81	.5
5	4.25	1.26	1.57	.25	.33	.75	.96	.6
	4.5	1.45	1.77	.3	.45	.83	1.38	.8
5	5	1.57	1.97	.35	.57	1.16	1.76	1
75	5.5	1.77	2.19	.45	.7	1.2	2.2	1.3
	5.75	1.96	2.36	.59	.83	1.6	2.63	1.5
	6.75	2.36	2.75	.85	1.08	2	4.21	2.3
5	7.75	2.75	3.14	1.1	1.43	2.65	4.83	3.1
	8.75	2.95	3.53	1.28	1.8	3.35	5.75	3.8
	9.75	3.14	3.93	1.45	2.3	4.6	7.5	4.8
5	10.5	3.53	4.32	1.83	2.94	4.92	9.33	5
5	11.75	3.93	4.71	2.33	3.56	5.83	10.6	[illegible]
	12.75	4.32	5.1	2.98	4	6.2	11.9	[illegible]
	14.75	4.71	5.5	3.58	4.8	8.7	14.5	[illegible]
	15.25	4.81	5.89	3.65	5.6	9	17.6	1[illegible]
	15.75	5.1	6.28	4.04	6.3		20	12
	17.75	5.8	7.07	5.65	7.9[illegible]		[illegible].3	15.[illegible]
	19.5	6.35	7.85	6.5	9.8[illegible]		[illegible]	19.6

xperiments of *U. S. Navy, hemp rope of this* ... -ealcing
of 71 309 lbs., and a wire rope of 5.34 ins. has
[illegible]

Weight of Hemp and Wire Rope. (Molesworth.)

In Lbs. per Fathom.

Circumference.	Hemp. Common.	Hemp. Good.	Wire. Iron.	Wire. Steel.	Circumference.	Hemp. Common.	Hemp. Good.
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Lbs.	Lbs.
1	.18	.24	.87	.89	5	4.5	6
1.5	.41	.54	1.96	2	5.5	5.45	7.26
1.75	.55	.74	2.66	2.73	6	6.48	8.64
2	.72	.96	3.48	3.56	6.5	7.61	10.14
2.25	.91	1.22	4.4	4.51	7	8.82	11.76
2.5	1.13	1.5	5.44	5.56	7.5	10.13	13.5
2.75	1.36	1.82	6.58	6.73	8	11.52	15.36
3	1.62	2.16	7.83	8.01	8.5	13.05	17.34
3.25	1.9	2.54	9.19	9.4	9	14.58	19.44
3.5	2.21	2.94	10.66	10.9	10	18	24
3.75	2.53	3.38	12.23	12.52	12	26	34.56
4	2.88	3.84	13.92	14.24	15	40.52	54

To Compute Stress upon a Rope set at an Inclination.

Rule.—Multiply sine of angle of elevation by strain in lbs., add an allowance for rolling friction and weight of rope, and multiply by factor of safety.

Factor of safety.—For standing rope 4, for running 5, and for inclined planes from 5 to 7.

Illustration.—Inclination of rope 92.5 feet in 100, velocity 1500 feet per minute, and strain 2000 lbs.; what should be diam. of iron rope, 7 wires to a strand?

Angle of 92.5 feet in $100 = 43°$, and sine of $43° = .682$. $.682 \times 2000 = 1364$, to which is to be added rolling friction and weight of rope, assumed to be 11; hence, $1364 + 11 = 1375$.

Factor of safety assumed at 6, consequently $1375 \times 6 = 8250$ *lbs., capacity or breaking weight or stress of rope.*

By table, page 162, 8200 lbs. is breaking weight of a wire rope of 7 strands, .605 *inch in diam.*

To Compute Tension of a Rope.

$\frac{\text{HP}}{v} = t.$ *v representing velocity of rope in feet per minute,* HP *horses' power, and t tension in lbs.*

Illustration.—Assume wheel 7 feet in diameter, revolution 140 per minute, and HP as per preceding table, 29.6.

$$\text{Then } \frac{29.6 \times 33\,000}{7 \times 3.1416 \times 140} = \frac{976\,800}{3079} = 317.2 \text{ lbs.}$$

To Compute Operative Deflection of a Rope.

$\frac{D^2 w}{10.7\, t} = d.$ D *representing distance between centres of wheels or drums in feet, w weight of rope in feet per lb., t tension, or power required to produce required power or tension of rope when at rest, and* d *deflection in feet.*

Illustration.—Take elements of preceding case: diam. of wire rope of 7 strands = .5625 inch, and by table, page 162, $w = .41$ lb., and $D = 300$ feet.

$$\text{Then } \frac{300^2 \times .41}{10.7 \times 317.2} = 10.87 \text{ feet.}$$

of the river Rhine there is a wire rope in operat
... horses for a distance exceeding one mil

Endless Ropes.

'e Ropes, when practicable and proper for application, can be used for aission of power at a less cost than belting or shafting.

Transmission of Power.

Revolutions per Minute.	Diameter of Rope.	Horse Power.	Diameter of Wheel.	Revolutions per Minute.	Diameter of Rope.	Horse Power.	Diameter of Wheel.	Revolutions per Minute.	Diameter of Rope.	Horse Power.
	Ins.		Feet.		Ins.		Feet.		Ins.	
80	.375	3.3	7	100	.5625	21.1	11	140	.6875	132.1
100	.375	4.1	7	140	.5625	29.6	12	80	.75	99.3
120	.375	5	8	80	.625	22	12	100	.75	124.1
140	.375	5.8	8	100	.625	27.5	12	140	.75	173.7
80	.4375	6.9	8	140	.625	38.5	13	80	.75	122.6
100	.4375	8.6	9	80	.625	41.5	13	100	.75	153.2
120	.4375	10.3	9	100	.625	51.9	13	120	.75	183.9
140	.4375	12.1	9	140	.625	72.6	14	80	.875	148
80	.5	10.7	10	80	.6875	58.4	14	100	.875	176
100	.5	13.4	10	100	.6875	73	14	120	.875	222
120	.5	16.1	10	140	.6875	102.2	15	80	.875	217
140	.5	18.7	11	80	.6875	75.5	15	100	.875	259
80	.5625	16.9	11	100	.6875	94.4	15	120	.875	300

Wire Rope and Equivalent Belt.

ubstituting wire rope for an ordinary flat belt, the diameter is deter- by rule in practice for estimating power transmitted by a belt—viz., horse power for every 70 square feet of running belt surface per . Thus, a belt 15 inches wide running at rate of 1400 feet per min- power would be equal to $(1400 \times 15) \div (70 \times 12) = 25$ horses' power. same result is obtained by the use of a wire rope .5625 inch in diam- unning over a wheel 6 feet in diameter, making 130 revolutions per .

age life of iron wire rope with good care is from 3 to 5 years, and steel rope is greater. Wear increases rapidly with velocity.

General Notes.—Hemp and Wire Ropes.

e Rope, 2 inches in circumference, of different manufactures, parted at of from 4413 to 6160 lbs.

mens of Italian, Russian, and French manufacture parted with an stress of 5128 lbs. = 1633 lbs. per square inch of rope.

ng capacity of a hemp rope is proportional to its thickness, number trands, slackness with which they are twisted, and quality of the

and Wire Ropes.—Ultimate Strength is 2240 lbs. per lb. per fathom d hemp, 3300 lbs. for iron, 7000 lbs. for cast-steel, and 10 000 lbs. for teel.

ing Load is 336 lbs. per lb. weight per fathom for round hemp, 660 iron, 1400 lbs. for cast-steel, and 2000 lbs. for plough-steel.

3 times square of circumference in inches for round hemp, 5 times f circumference for iron, and 9 times square of circumferen *D. K. Clark.*)

Ropes may be one half less in weight than iron or hemp *loads.*

IRON WIRE AND UNITED STATES NAVY HEMP ROPE.

Wire 6 Strands, Hemp Core. Rope 4 Strands.

WIRE.					HEMP.			
Circumference.		Core.	Wires.	Breaking Weight.	Circumference.		Yarns.	Breaking Weight.
Actual.	Nominal.				Actual.	Nominal.		
Ins.	Ins.	Ins.	No.	Lbs.	Ins.	Ins.	No.	Lbs.
7	7	2.35	108	187 400	12	13.25	1168	75 966
6	6	2.25	108	104 050	11	12.25	1036	77 633
4.937	4.9	1.57	114	65 409	10.5	11.875	928	76 933
4.375	4.5	1.57	114	55 316	10	11.375	876	70 533
3.5	3.36	1.27	114	34 480	9.5	10.5	800	58 766
3.187	2.98	1.17	114	28 606	9	10.312	712	56 466
2.75	2.68	.78	114	21 846	8.5	9.437	640	42 866
2.5	2.45	.78	114	15 692	8	8.812	560	40 000
2.375	2.4	.78	42	15 718	7.5	8.437	484	35 500
2	2.06	.39	114	10 925	7	7.812	436	32 166

Weight and Strength of Stud-link Chain Cable.

(English.)

DIMENSIONS.			Weight per Fathom.	Admiralty Proof-stress (adopted by Lloyds').	DIMENSIONS.			Weight per Fathom.	Admiralty Proof-stress (adopted by Lloyds').
Diam. of each Side.	Length of Link.	Width of Link.			Diam. of each Side.	Length of Link.	Width of Link.		
Ins.	Ins.	Ins.	Lbs.	Tons.	Ins.	Ins.	Ins.	Lbs.	Tons.
.4375	2.625	1.575	11.3	3.5	1.5	9	5.4	121	40.5
.5	3	1.8	13.4	4.5	1.625	9.75	5.85	142	47.5
.5625	3.375	2.025	17.2	5.5	1.75	10.5	6.3	164.6	55.125
.625	3.75	2.25	21	7	1.875	11.25	6.75	189	63.25
.6875	4.125	2.475	25.4	8.5	2	12	7.2	215	72
.75	4.5	2.7	30.2	10.125	2.125	12.75	7.65	242.8	81.25
.875	5.25	3.15	41.2	13.75	2.25	13.5	8.1	276.2	91.125
1	6	3.6	53.8	18	2.375	14.25	8.55	303.2	101.5
1.125	6.75	4.05	69	22.75	2.5	15	9	336	112.5
1.25	7.5	4.5	84	28.125	2.75	16.5	9.9	406.6	136.125
1.375	8.25	4.95	101.6	34					

NOTE 1.—*Safe Working-stress* is taken at half Proof-stress, 3.82 tons per sq. inch of section.

2.—*Proof-stress* and *Safe Working-stress* for close-link chains are respectively two-thirds of those of stud-link chains.

3.—*Proof-stress* averages 72 per cent. ultimate strength, and *Ultimate Strength* averages 8 tons per square inch of section of rod or one side of a link.

Weight of close-link chain is about three times weight of bar from which it is made, for equal lengths.

Karl von Ott, comparing weight, cost, and strength of the three materials, hemp, iron wire, and chain iron, concludes that the proportion between cost of hemp rope, wire rope, and chain is as 2 : 1 : 3, and that, therefore, for equal resistances, wire rope is only half the cost of hemp rope, and a third of cost of chains.

Safe Working Load of Chains. (*Molesworth*).

Diameter of Iron.	Load.	Diameter of Iron.	Load.	Diameter of Iron.	Load.	Diameter of Iron.	Load.
Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
[illegible]	2240	.6875	7 390	.9375	13 700	1.1875	[illegible]
[illegible]	3800	.75	8 960	1	15 680	1.25	[illegible]
[illegible]	4900	.8125	10 280	1.0625	17 920	1.3125	[illegible]
[illegible]	6270	.875	12 320	1.125	20 160	1.375	[illegible]

Breaking Strain and Proof of Chain Cables.

Diam. Chain.	Breaking Strain.	Diam. of Chain.	Breaking Strain.	Diam. of Chain.	Breaking Strain.	Diam. of Chain.	Breaking Strain.
Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
	67 700	1.1875	92 940	1.5	143 100	2	243 180
0625	75 640	1.25	102 160	1.625	165 920	2.125	272 580
125	84 100	1.375	121 840	1.75	216 120	2.25	303 280

'roof-stress is 50 per cent. of estimated strength of weakest *link* and 46 cent. of strongest.

mparison of Wire Ropes and Tarred Hemp Rope, Hawsers, and Cables.

COARSE LAID.							FINE LAID.				
			Ropes.		Haws'rs.	Cables.			Ropes.	Haws'rs.	Cables.
n-	Circum.	Safe Load.	Three Strands.	Four Strands.	Three Strands.	Three Strands.	Diameter.	Safe Load.	Four Strands.	Three Strands.	Three Strands.
	Ins.	Lbs.	Ins.	Ins.	Ins.	Ins.	Ins.	Lbs.	Ins.	Ins.	Ins.
	.78	425	1.25	—	—	—	.5	1 875	3.12	2.87	—
25	1	690	2.43	2.25	3.32	—	.5625	2 420	3.56	3.25	4.87
	1.25	825	2.68	2.375	3.5	—	.625	2 900	3.93	3.62	5.25
	1.375	1 600	2.87	2.62	3.87	—	.75	4 320	4.81	4.37	6.37
5	1.75	2 800	3.81	3.5	5.18	—	.875	5 700	5.5	5	7.25
5	2.125	3 800	4.75	4.25	6.12	—	1	8 200	7.25	6.25	8.75
	2.375	4 400	5.25	4.87	7	—	1.125	10 100	8.18	7	9.5
	2.625	6 150	6.12	5.75	8	8	1.25	13 600	8.81	8.06	11
	3	8 400	6.62	6.12	8.62	8.62	1.5	17 500	10	9.75	12.5
	3.75	13 400	8.81	8.5	10.93	10.93	1.625	21 800	11.18	10.93	—
	4.25	16 800	9.87	9.56	12.25	12.12	1.75	27 000	12.5	12.12	—
	4.625	20 160	10.75	10.5	13	13.12	1.875	32 500	—	—	—
	5	24 600	—	11.87	11.56	11.75	2	37 000	—	—	—

above table, determination of circumference of rope, etc., is based upon king Weight or Tensile resistance of wire being reduced by one fourth, ultimate resistances of rope, etc., are reduced one third.

ult of Experiments upon Wire Rope at U. S. Navy Yard, Washington. (*J A. Roebling's Sons.*)

nference.		Wire in each Strand.	Diam. of Wire by W. G.	Weight per Foot.	Breaking Weight.	Circumference.		Wire in each Strand.	Diam. of Wire by W. G.	Weight per Foot.	Breaking Weight.
l.	Nominal.					Actual.	Nominal.				
	Ins.	No.	No.	Lbs.	Lbs.	Ins.	Ins.	No.	No.	Lbs.	Lbs.
5	4.9	19	11	3.14	65 409	2.375	2.4	7	13	14	15 718
	4.5	19	13	2.15	55 316	2.1875	2.12	7	14	.1	14 478
5	3.91	19	14	2.0875	44 420	2	2.06	19	19		10 925
	3.36	19	14	1.1525	34 840	1.9375	1.9	7	14		10 118
5	2.98	19	15	1.09	28 606	1.75	1.85	7	17	.07	7 880
	2.68	19	17	1.0275	21 846	1.4375	1.45	19	20	.06	5 687
5	2.56	7	13	1.0225	18 810	1.3125	1.31	7	18	.05	4 428
	2.45	19	18	.14	15 692	1.125	1.11	7	19	.035	3 729

Compute Circumference of Wire Rope with Hemp ore, of Corresponding Strength to Hemp Rope, and Hemp Rope to Circumference of Wire Rope.

LE 1.—Multiply square of circumference of hemp rope by .223 for iron and .12 for steel, and extract square root of product.

·Multiply square of circumference of hemp-core wire rope by 4.5 for ire and 8.4 for steel wire.

MPLE.—What are the circumferences of an iron and steel wire rope corresponding to one *of hemp-core, having* a circumference of 8 ins.?

$\sqrt{8^2 \times .223} = 3.78$ *ins. iron*, and $\sqrt{8^2 \times .12} = 2.77$ ins. steel.

ROPES, HAWSERS, AND CABLES.

Ropes of hemp fibres are laid with three or four strands of twisted fi and are made up to a circumference of 12 ins., and those of four stran to 8 ins. are fully 16 *per cent.* stronger than those of three strands.

Hawsers are laid with three or four strands of rope. *Cables* are laid but three strands of rope. Hawsers and Cables, from having a less pr tionate number of fibres, and from the irregularity of the resistance of fibres in consequence of the twisting of them, have less strength than r difference varying from 35 to 45 *per cent.*, being greatest with least cir ference, and those of three strands up to 12 ins. are fully 10 *per cent.* st er than those having four strands.

Tarred ropes, hawsers, etc., have 25 *per cent.* less strength than ropes; this is in consequence of the injury fibres receive from the high perature of the tar, viz. 290°.

Tarred hemp and Manila ropes are of about equal strength, and have 25 *to* 30 *per cent.* less strength than white ropes.

White ropes are more durable than tarred.

The greater degree of twisting given to fibres of a rope, etc., les strength, as exterior, alone resists greater portion of strain.

Ultimate strength of ropes varies from 7000 to 12 000 lbs. per square of section, according as they are wetted, tarred, or dry. One sixth of mate strength is a safe working load = 1166 to 2000 lbs. per square inc

Units for computing Safe Strain that may be borne New Ropes, Hawsers, and Cables. (*U. S. Navy.*)

Description.	Circumference.	Ropes. White. 3 strands.	Ropes. White. 4 strands.	Ropes. Tarred. 3 str'ds.	Ropes. Tarred. 4 str'ds.	Hawsers. White. 3 str'ds.	Hawsers. Tarred. 3 str'ds.	Cable White. 3 str'ds.	T 3
	Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
White	2.5 to 6	1140	1330	—	—	600	—	—	
"	6 " 8	1090	1260	—	—	570	—	510	
"	8 " 12	1045	880	—	—	530	—	530	
"	12 " 18	—	—	—	—	550	—	550	
"	18 " 26	—	—	—	—	—	—	560	
Tarred	2.5 " 5	—	—	855	1005	—	460	—	
"	5 " 8	—	—	825	940	—	480	—	
"	8 " 12	—	—	780	820	—	505	—	
"	12 " 18	—	—	—	—	—	—	—	
"	18 " 26	—	—	—	—	—	—	—	
Manila	2.5 " 6	810	950	—	—	440	—	—	
"	6 " 12	760	835	—	—	465	—	510	
"	12 " 18	—	—	—	—	—	—	535	
"	18 " 26	—	—	—	—	—	—	560	

ILLUSTRATION.—What weight can be borne *with safety* by a Manila rope strands, having a circumference of 6 inches? *(See Rule, page* 167.)

$$6^2 \times 760 = 27\,360 \ lbs.$$

When it is required to ascertain weight or strain that can be born ropes, etc., in general use, preceding Units should be reduced from *one t to two thirds*, in order to meet their condition or reduction of their stre by chafing and exposure to weather. Molesworth's table is based up reduction of three fourths.

ILLUSTRATION.—What weight can be borne by a tarred hawser of 3 strand inches in circumference, in *general use*?

$$10^2 \times (505 - \overline{505 \div 3}) = 100 \times 336.67 = 33\,667 \text{ lbs.}$$

Destructive Strength of Tarred Hemp Ropes.

(*D. K. Clark.*)

rcum.	Diam.	Register. Common Cold.	Register. Russian Warm.	Circum.	Diam.	Register. Common Cold.	Register. Russian Warm.
Ins.	Ins.	Lbs.	Lbs.	Ins.	Ins.	Lbs.	Lbs.
3	.95	7 390	8 620	5.5	1.75	24 800	29 120
3.5	1.11	11 200	11 760	6	1.91	28 985	33 150
4	1.27	13 100	15 340	6.5	2.07	34 030	40 550
4.5	1.43	16 330	19 440	7	2.24	40 320	47 041
5	1.59	19 580	23 990	8	2.54	52 480	61 420

ecimens furnished by National Association of Rope and Twine Spinners, As tested by Mr. Kirkaldy.

Rope.	Circumference.	Weight per Lb.	Extreme Strength.	Breaking Weight per lb. per Fathom.	Extension in 50 ins. Length at Stress per lb. Weight per Fathom of 1000 lbs.	2000 lbs.	3000 lbs.
	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Ins.
ssian rope . . . 48 thr'ds.	5.26	.926	11 088	1933	5.29	—	—
chine yarn. . . 50 "	5.37	.891	11 514	2152	4.53	6.56	—
nd-spun yarn, 51 "	5.39	1.006	18 278	3024	4.46	5.91	6.63

eaking Strength of Tarred Hemp Ropes. (*Mr. Glynn.*)

Diam.	Old Method. Common Hemp.	Old Method. Best Russian.	By Register. Cold.	By Register. Warm.	Circum.	Diam.	Old Method. Common Hemp.	Old Method. Best Russian.	By Register. Cold.	By Register. Warm.
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Lbs.	Lbs.	Lbs.	Lbs.
.95	5 056	6 248	7 392	8 624	5.5	1.75	15 456	18 414	24 797	29 120
1.11	7 466	8 668	11 200	11 760	6	1.91	18 144	21 610	28 986	33 150
1.27	8 780	10 460	13 104	17 810	6.5	2.07	20 518	23 610	34 630	40 544
1.43	10 300	12 432	16 330	19 443	7	2.24	22 938	27 462	40 320	47 040
1.59	13 328	15 859	20 496	23 990	8	2.54	26 680	32 032	52 483	61 420

Compute Strain that may be borne with safety by new Ropes, Hawsers, and Cables.

educed from experiments of Russian Government upon relative strength ifferent Circumferences of Ropes, Hawsers, etc.

. S. Navy test is 4200 *lbs. for a White rope of three strands of best Riga), of* 1.75 *inches in circumference* (= 17 000 *lbs. per square inch of fibre*), *n preceding table* (page 166) 14 000 *lbs. is taken as unit of strain that be borne with safety.*

JLE.—Square circumference of rope, hawser, etc., and multiply it by s in table.

Compute Circumference of a Rope, Hawser, or Cable for a Given Strain.

JLE.—Divide strain in pounds by appropriate units in preceding table, square root of product will give circumference of rope, etc., in ins.

AMPLE I.—Stress to be borne in safety is 165 550 lbs.; what should be circumce of a tarred cable to withstand it?

$$165\,552 \div 550 = 301, \text{ and } \sqrt{301} = 17.35$$

-What should be circumference of a Manila cable a strain, in *al use*, of 149 336 lbs.?

suming *circumference to exceed* 18 ins., unit = 560.

$$149\,336 \div (560 - \overline{560 \div 3}) = 400, \text{ and } \sqrt{40}$$

To Compute Weight of Ropes, Hawsers, and Cables.

RULE.—Square circumference, and multiply it by appropriate unit i following table, and product will give weight per foot in lbs.:

	Ropes.	Hawsers. Cables.			Ropes.	Hawsers. Cable
3-strand Hemp	.032	.031	.031	4-strand Hemp	.033	—	—
3-strand tarred Hemp	.042	.041	.041	4-strand tarred Hemp	.048	—	—
3-strand Manila	.032	.031	.031	4-strand Manila	.035	.034	.034

Units for Thread Ropes is same as that for Ropes of like material.

EXAMPLE.—What is weight of a coil of 10-inch Manila hawser of 4 strands of 12 fathoms?

$$10^2 \times .034 = 3.4, \text{ and } 120 \times 6 \times 3.4 = 2448 \text{ lbs.}$$

Weight and Strength of Hemp and Wire Ropes.
(*Molesworth.*)

$$C^2 y = W; \qquad C^2 k = L; \qquad C^2 x = S; \qquad \text{and} \sqrt{\frac{L}{k}} = C.$$

C *representing circumference in ins.*, W *weight of rope in lbs. per fathom*, L *working load in tons, and* S *destructive stress in tons.*

VALUES OF y, x, AND k.

Ropes.	y	x	k	Ropes.	y	x	k
Hawser, hemp	.131	—	—	Warm register, hemp	—	.7	.1[illegible]
Cable "	.117	—	—	Manila hawser	.177	.27	.04[illegible]
Tarred hawser, hemp.	.235	.22	.037	" cable	.155	.19	.03[illegible]
" cable, "	.207	.15	.025	Iron rope	.87	1.8	.29
Cold register, "	—	.6	.1	Steel "	.89	2.8	.45

To Compute Circumference of Hemp or Wire Rope for Fore or Main Standing Rigging. (*U. S. Navy.*)

RULE.—To length of mast between partners and deck, add half extreme breadth of beam of vessel and divide sum by half extreme breadth. Multiply quotient by half square root of tonnage (OM) and extract square root of product.

For Mizzen, take .74 of Fore and Main.

EXAMPLE.—Required circumference of hemp rope, for main-mast of a vessel having a breadth of beam of 45 feet and a burden of 3213 tons?

Extreme length of mast		94.4 feet.	
Depth of hold, or total bury of mast,	21.4 feet.		
Head	15 "	36.4	"
Breadth of beam, 45 feet.		58	"

$$58 + \frac{45}{2} \div \frac{45}{2} = 3.58, \text{ and } \sqrt{\left(3.58 \times \frac{\sqrt{3213}}{2}\right)} = \sqrt{101.46} = 10.11 \text{ ins.}$$

Then if circumference for a wire rope is required, see table, page 164.

Thus, a hemp rope 10 ins. in circumference has equivalent strength of an iron wire rope of 4 ins. and a steel rope of 3.25+ ins.

Galvanized Iron Wire.—Experiments at Navy Yard, Washington, gave for flexibility a mean loss of 30 per cent., and for tensile strength a like loss of 13.5 per cent.

Relative Dimensions of Hemp Rope and Iron and Steel Wire Rope. (*U. S. Navy.*)

Circumference in Inches.

[illegible]	4	4.5	5.25	6.5	7.75	8.5	9.5	11	11.75	13.5	16
				3	3.5	4	4.5	5	5.5	6	7
				2.125	2.5	2.75	3.25	3.5	4	4.375	[illegible]

ANCHORS, CABLES, ETC.

rs, Chains, etc., for a Given Tonnage.

(*American Shipmasters' Association.*)

SAILS.

Anchors.				Chain Cable.—Stud.			Weights per Fathom.		
	Including Stock.								
...dility ...ed.	Stream.	Kedge.	2d Kedge.	Diameter.†	Length.	Admiralty Test.	Stud.	Short Link.	English.*
...ons.	Lbs.	Lbs.	Lbs.	Ins.	Fathms.	Tons.	Lbs.	Lbs.	
7	168	84	—	.8125	90	11	40	42	35
8	196	112	—	.875	105	13	44	45	—
9	224	112	—	.9375	105	15	51	55	48
0	280	140	—	1	120	17.5	59	63	54
1	336	168	—	1.0625	120	20	60	70	—
2	392	196	—	1.125	120	22.5	75	79	68
3	448	224	112	1.1875	135	25	82	88	—
4	504	252	126	1.25	135	28	91	98	84
5.5	560	280	140	1.3125	150	31	100	106	—
7	616	308	154	1.3125	150	31	100	106	—
8.5	672	336	168	1.375	165	37	115	118	102
0	784	392	196	1.4375	165	40	120	—	—
2	896	448	224	1.5	180	44	132	—	122
4	1008	504	252	1.5625	180	47	145	—	—
6	1120	560	280	1.625	180	51	150	—	143
8	1232	616	308	1.6875	180	55	162	—	—
9.5	1344	672	336	1.75	180	59	175	—	166
1	1456	738	364	1.875	180	63	189	—	191
2.5	1568	784	392	1.9375	180	67	205	—	—
4	1680	840	420	2	180	72	219	—	—
5.5	1792	896	448	2	180	72	240	—	217
7	1904	952	504	2.0625	180	81	—	—	—
9	2128	1120	560	2.125	180	86	—	—	244
1	2353	1232	616	2.1875	180	90	—	—	—

† Brown, Lenox, & Co.

To Compute Tonnage.

sions as follows: *Length.*—From after-side of stem to fore-... tern-post, measured on spar or upper deck in vessels having ... under, and on main deck in vessels having three or more ... th.—Extreme at widest point. *Depth.*—At forward coaming ... from top of ceiling at side of keelson to under side of deck. ... ply these dimensions together, divide product by 100, and ... tient.

... have 2 bowers and 1 each stream and kedge anchor, and for ... nding 1400 a third bower is recommended.

... *Warps* to be 90 fathoms in length.

Shrouds.

...GED. *Hemp.*—5.75 ins. in diameter for a tonnage of [illegible] ... ssively up to 12.75 ins. for 3000 tons.

... RIGGED. From .25 to 1 inch in diameter [illegible] ... wo-rigged.

...ameter of hemp, increasing very slightly as ... 000 tons. 12.75 ins. for hemp and 6.875 ins.

P*

(*American Shipmasters' Association.*)

STEAM.

Tonnage computed as per Rule preceding.	Anchors. Bowers. Without Stock.	Anchors. Bowers. Admiralty Test.	Including Stock. Stream.	Including Stock. Kedge.	Including Stock. 2d Kedge.	Chain Cable.—Stud. Diameter.	Length.	Admiralty Test.	Diam. Stream.	Weight per Fa Stud.	Weight per Fa Short Link.
	Lbs.	Tons.	Lbs.	Lbs.	Lbs.	Ins.	Faths.	Tons.	Ins.	Lbs.	Lbs.
100	336	4.9	112	—	—	.6875	105	8.1	.5	—	—
150	448	6.4	196	—	—	.8125	120	11.9	.5625	40	42
200	616	7.6	224	—	—	.875	120	13.8	.5625	44	48
250	672	8.2	280	—	—	.9375	120	15.8	.625	51	55
300	812	9.5	308	—	—	1	120	18	.625	59	63
350	924	10.4	336	—	—	1.0625	120	20.3	.6875	66	70
400	1120	12	532	252	—	1.125	135	22.8	.6875	75	79
450	1344	13.9	560	280	—	1.1875	135	25.4	.75	82	88
500	1512	15.2	672	336	—	1.25	150	28.1	.75	91	98
600	1708	16.7	738	364	—	1.3125	150	31	.8125	100	106
700	1876	18	784	392	—	1.375	165	34	.8125	115	118
800	2026	19	896	448	224	1.4375	165	37.2	.875	120	—
900	2352	21.6	1008	504	252	1.5	180	40.5	.875	132	—
1000	2632	23.5	1120	560	280	1.5625	180	44	.9375	145	—
1200	2856	25.2	1176	588	308	1.625	180	47.5	.9375	156	—
1400	3108	26.9	1232	616	308	1.6875	180	51.2	1	162	—
1600	3360	28.6	1344	672	336	1.75	180	55.1	1	175	—
1800	3584	30.1	1456	738	364	1.8125	180	59.1	1.0625	189	—
2000	3808	31.6	1512	766	364	1.875	180	63.3	1.0625	205	—
2300	4088	33.4	1568	784	392	1.9375	180	67.6	1.125	215	—
2600	4256	34.5	1624	812	392	2	270	72	1.125	240	—
3000	4480	35.7	1680	840	420	2.0625	270	76.6	1.1875	—	—
3500	4592	37	1792	896	476	2.125	270	81.3	1.1875	—	—
4000	4816	38	1960	952	504	2.1875	270	86.1	1.25	—	—
4500	5040	39.2	2128	1064	532	2.25	270	91.1	1.25	—	—
5000	5264	41	2352	1120	560	2.3125	270	96	1.3125	—	—

* Brown, Lennox, & Co.

ANCHORS AND KEDGES.

(*U. S. Navy.*)

To Compute Weight of a Bower Anchor for a Ves[sel] of a given Character and Rate.

RULE.—Multiply approximate displacement in tons, by unit in follow[ing] table, and product will give weight in lbs., inclusive of stock.

Units to determine Weights and Number of Anch[ors] or Kedges.

Displacement of Vessel in Tons.	Unit.	Bower.	Sheet.	Stream.	Kedge.	Displacement of Vessel in Tons.	Unit.	Bower.	Sheet.
Over 3700	1.75	2	2	1	4	Over 1500 ..	2.5	2	2
" 2400	2	2	2	1	3	" 900 ..	2.75	2	1
" 1900	2.25	2	2	1	3	900 and under	3	2	1

EXAMPLE.—Tonnage of a bark-rigged steamer is 1500.

1500 × 2.5 = 3750 *lbs., weight of anchor.*

...r *and Sheet Anchors* should be alike in weight.

Anchors and *Kedges* are proportional to weight of bowers. ... *anchor* .25 weight. Kedges.—If 1, .125 weight; if 2, .16 ... 3, .16, .125, and .1 weight.

›mpute Diameter of a Chain Cable corresponding to a Given Weight of Anchor.

(*U. S. Navy.*)

.—Cut off the two right-hand figures of the anchor's weight in lbs., r square root of remainder by 4, and result will give diameter of sixteenths of an inch.

LE.—The weight of an anchor is 2500 lbs.

$\sqrt{25.00} \times 4 = 20$ *sixteenths* $= 1.25$ *ins.*

–Diam. of a messenger should be .66 that of the cable to which it is applied.

Lengths of Chain Cables for each Anchor.

(*U. S. Navy.*)

Anchor.	Bower.	Sheet.	Stream.	Weight of Anchor.	Bower.	Sheet.	Stream.
ι.	Fathoms.	Fathoms.	Fathoms.	Lbs.	Fathoms.	Fathoms.	Fathoms.
800	60	60	60	Over 2000	120	120	90
800	90	90	60	" 3000	120	120	90
1200	90	90	75	" 5000	120	120	105
1600	105	105	75	" 7500	135	135	105

ANCHORS.

Experiments of a Joint Committee of Representatives of Ship-owners and Admiralty of Great Britain.

nchor of ordinary or Admiralty pattern, Trotman or Porter's im-(pivot fluke), Honiball, Porter's, Aylin's, Rodgers's, Mitcheson's, and 's, each weighing, inclusive of stock, 27000 lbs., withstood without ι proof strain of 45000 lbs.

ting weights between a Porter and Admiralty anchor, as tested at ch Dock-yard, were as 43 to 14.

Comparative Resistance to Dragging.

nan's dragged Aylin's, Honiball's Mitcheson's and Lennox's; Aylin's tcheson's dragged Rodgers's; and Rodgers's and Lennox's dragged lty's.

TONNAGE OF VESSELS.

To Compute Tonnage of Vessels.

aws of United States of America, with amendments of 1882 relative n-vessels, see Mechanics' Tables, with rule and illustrated diagrams, ι. H. Haswell, 3d edition, Harper & Bros., New York, 1878.

English Registered Tonnage. (*New Measurement.*)

ι length of upper deck between after-part of stem and fore-part of stern-ι 6 equal parts, and note foremost, middle, and aftermost points of division. depths at these three points in feet and tenths of a foot; also depths from le of upper deck to ceiling of limber-strake; or in case of a break in the ck, from a line stretched in continuation of the deck. For breadths, divide th into 5 equal parts, and measure the inside breadths at following points, t .2 and .8 from upper deck of foremost and aftermost depths; and from from upper deck of amidship depth. Take length at half amidship depth er-part of stem to fore-part of stern-post.

to twice amidship depth add foremost and aftermost depths for *sum of* nd add together foremost upper and lower breadths, 3 times upper breadth er breadth at amidship, and upper and twice lower breadth at after division *of breadths.*

ly together sum of depths, sum of breadths, and length, and divide product which will give number of tons.

vessel has a poop or half-deck, or a break in upper deck, measure ngth, *breadth, and height* of such part thereof as may be included ed; *multiply these three* measurements together, divide product at *will give number of tons* to be added to result as above asce

For Open Vessels.—Depths are to be taken from upper edge of upper strake.

For Steam Vessels.—Tonnage due to engine-room is deducted from total tonnage computed by above rule. To determine this, measure inside of the engine-room from foremost to aftermost bulkhead; then multiply this length by amidship depth of vessel, and product by inside amidship breadth at .4 of depth from deck, and divide final product by 92.4.

The volume of the poop, deck-houses, and other permanently enclosed spaces, available for cargo or passengers, is to be measured and included in the tonnage, but following deductions are allowed, the remainder being the *Register tonnage.*

Deductions.—Houses for the shelter of passengers only; space allotted to crew (12 square feet in surface and 72 cube feet in volume for each person); and space occupied by propelling power.

Approximate Rule.

Gross Register.—Tonnage of a vessel expresses her entire cubical volume in tons of 100 cube feet each, and is ascertained by following formula:

$\frac{L\,B\,D}{100} =$ *Gross tonnage*, and $\frac{L\,B\,D}{100}\,c =$ *Register tonnage.* L *representing length of keel between perpendiculars,* B *breadth of vessel, and* D *depth of hold, all in feet.*

Builders' Measurement.

$$\frac{(L - .6\,B) \times B \times .5\,B}{94} = \textit{Tonnage.}$$

Fore-perpendicular is taken at fore-part of stem at height of upper deck.
Aft-perpendicular is taken at back of stern-post at height of upper deck.
In three-deckers, middle deck is taken instead of upper deck.
Breadth is taken as extreme breadth at height of the wales, subtracting difference between thickness of wales and bottom plank. Deductions to be made for rake of stem and stern.

Iron Vessels. $\frac{18}{10\,000}\left(\frac{\textit{Girth} + \textit{Breadth}}{2}\right)^2 \times \textit{length} = \textit{Gross tonnage.}$

Length measured on upper deck, between outside of outer plank at stem and the after-side of stern-post and rabbet of stern-post, at point where counter-plank crosses it. Girth measured by a chain passed under bottom from upper deck at extreme breadth, on one side, to corresponding point on the other.

Register tonnage $= \frac{L \times B \times D}{100} \times C.$ C *representing a coefficient for vessels as follows:*

Ships of usual form	.7	Yachts above 60 tons	.5
Clippers and Steamers, 2 decks	.65	Small vessels, sharp	.45
Clippers and Steamers, 3 "	.68	Small vessels, very sharp	.4

Units for Measurement and Dead-weight Cargoes.

(*C. Mackrow, M. S. N. A.*)

To Compute Approximately for an Average Length of Voyage the Measurement Cargo, at 40 feet per Ton, which a Vessel can carry.

Rule.—Multiply number of register tons by unit 1.875, and product will give approximate measurement cargo.

To Compute Approximately Dead-weight Cargo in Tons which a Vessel can carry on an Average Length of Voyage.

Rule.—Multiply number of register tons by 1.5, and product will give approximate dead-weight cargo required.

With regard to cargoes of coasters and colliers, as ascertained above, about ... *per cent. may be added to said results, while about 10 per cent. may be* ...*ducted in cases of larger vessels on longer voyages.*

. case of measurement cargoes of steam-vessels, spaces occupied by ma-ery, fuel, and passenger cabins under the deck must be deducted from e or tonnage under deck before application of measurement unit thereto.

. case of dead-weight cargoes, weight of machinery, water in boilers, and must be deducted from whole dead weight, as ascertained above by ication of dead-weight unit.

ıe deductions necessary for provisions, stores, etc., are allowed for in :tion of the two units.

ıscertain Weight of Cargo for an Average Length of Voyage. (*Moorsom.*)

ɔduct tonnage of spc.:es of passenger accommodations from net register age, and multiply remainder by 1.5.

verage space for each ton weight of cargo on such a voyage 67 cube feet.

Freight Tonnage or Measurement Cargo.

eight Tonnage or *Measurement Cargo* is 40 cube feet of space for cargo, it is about 1.875 times net register tonnage less that for passenger space.

Royal Thames Yacht Club.

asure length of yacht in a straight line at deck from fore-part of stem to after-of stern-post, from which deduct extreme breadth (measured from outside of de planking), both in feet; remainder is length for tonnage. Multiply length onnage by extreme breadth, that product by half extreme breadth, divide re-ɔy 94, and quotient will give tonnage.

ıny part of stem or stern-post projects beyond length as taken above, such ction or projections shall, for purpose of computing tonnage, be added to length ı as before mentioned.

fractional parts of a ton are to be considered as a ton.

ısurements to be taken either above or below main wales.

$$\frac{L - B \times B \times .5\,B}{94} = Tons.$$ *L representing length and B breadth, in feet.*

Corinthian and New Thames Yacht Club.

sure length and breadth as in foregoing rule, and depth to top of covering : multiply length, breadth, and depth together, divide result by 200, and quo-rill give tonnage.

$$\frac{L \times B \times D}{200} = Tons.$$

Suez Canal Tonnage.

s Tonnage.—Spaces under tonnage deck, below tonnage and uppermost deck. ered or closed-in spaces, such as poop, forecastle, officers' cabins, gall-eck, and wheel houses, and all inclosed or covered-in spaces for working

ı which are to be deducted berthing accommodations for crew, not incluc ·or stewards and passengers' servants; berthing accommodations for offic captain; galleys, cook-houses, etc., used exclusively for crew, and inclc above uppermost deck, designed for working the vessel. In none of tl ɔan passengers be berthed or cargo carried, and total deduction under all ıces must not exceed 5 per cent. of gross tonnage.
amers with standing coal-bunkers, English rule may be followed, or owne ct to have tonnage of his vessel computed by "Danube rule," which is an ɔe of 50 per cent. above space allowed to machinery in side-wheel stea- n screw steamers.
case, however, except with tow-boats, must deduction for p *o per cent. of gross tonnage.*

WORKS OF MAGNITUDE.

American.

Aqueducts, Roads, and Railroads.

Croton Aqueduct, N. Y. — Has a section of 53.34 square feet and capacity of 100 000 000 to 118 000 000 gallons per day, and from Dam to Receiving Reservoir is 38.134 miles in length.

Aqueduct, Washington.—Cylinder of masonry 9 feet in diameter. Stone arch over Cabin John's Creek, 220 feet span, 57.25 feet rise.

National Road.—Over the Alleghany Mountains, Cumberland to Illinois Town, 650.625 miles in length, and 80 feet in width. Macadamized for a width of 30 feet.

Illinois Central Railroad.—Chicago to Cairo, length 365 miles, Centralia to Dunleith 344 miles, total 709 miles.

Bridges.

Suspension Bridge, Niagara River.—Wire, Span 1042 feet 10 ins.

Suspension Bridge, New York and Brooklyn. — Length of river span 1595 feet 6 ins.; of each land span 930 feet; length of Brooklyn approach 971 feet; of N. Y. approach 1562 feet 6 ins.; total length of bridge 5989 feet; width 85 feet; number of cables 4; diameter of each cable 15.5 ins.; each consisting of 6300 parallel steel wires No. 7 gauge, closely laid and wrapped to a solid cylinder; ultimate strength of each cable 11 200 tons; depth of tower foundation below high water, Brooklyn, 45 feet—New York 78 feet; towers at high-water line 140×59 feet; towers at roof course 136×53 feet; total height of towers above high water 277 feet; clear height of bridge in centre of river span above high water, at 50°, 135 feet; height of floor at towers above high water 119 feet 3 ins.; grade of roadway 3 feet in 100; anchorages, at base 129×119 feet, at top 117×104 feet; weight of each anchor-plate 23 tons.

Iron Pipe Bridge over Rock Creek.—200 feet span, 20 feet rise. Arch of 2 lateral courses of cast-iron pipe, 4 feet internal diameter, and 1 inch thick. These pipes conveying the water not only sustain themselves over the great span, but support a street road and railway.

Iron Bridge over Kentucky River near Shakers' Ferry, Md.—3 spans, each 375 feet, and 275.5 feet above low water.

Bridge on line of New York, Erie, and Western Railroad across the Kinzua.—Of iron; length 2060 feet; central span 301 feet in height.

Iron Truss.—Cincinnati and Southern Railway, over Ohio River, 519 feet.

Foreign.

Pyramids, Statues, etc.

Pyramid of Cheops, Egypt.—Length of side at base 762 feet; height to present summit 453.3 feet; to original summit 485.2 feet; inclined length 568.25 feet; angle of side 51° 51′ 14″; area of each face = square of height; weight 5 272 600 tons; built 2170 years B.C.

Peter the Great, St. Petersburg, Russia.—Bronze; height of horse 17 feet; of man 11 feet; base of rock 42 feet at bottom, 36 at top, 21 wide, and 17 high, weighing 1100 tons.

Liberty, New York Harbor.—Bronze; 110 feet in height from head to foot and 151.1 feet to flambeau; including base, 305.6 feet. Weight of statue 225 tons.

Daibutsu, of stone, Japan. —Sitting posture; height 44 feet, circumference 87 feet; face 8.5 feet; circumference of thumb 3.5 feet.

Colossus of Rhodes.—Height, 105 feet.

Bridge.

…lar Bridge.— Of iron, with a double line of Railway, 964 feet in …pproaches of 230 feet each. Weight 3658 tons.

Monoliths.

Obelisk at Karnak, Egypt.—Of granite, 108 feet 10 ins.; pedestal 13 feet 2 ins.; ght 400 tons.

Obelisk in Central Park, N. Y.—Of granite, 68 feet 11 ins.; weight 168 tons.

U. S. Treasury, Washington.—Some stones of, are heavier than any in the Pyra-ls of Egypt.

Steam Hammers.

At workshops of Herr Krupp, at Essen, there is a steam hammer weighing 50 tons ring a fall of 3 metres; and at Creusot there is a hammer weighing between 75 l 80 tons having a fall of 5 metres.

Crane.

At Creusot there is a steam crane having a capacity to lift and revolve with 150 s.

Chimneys.

. Townsend's chemical works, Glasgow, diameter at foundation 50 feet; at top eet 8 ins.; height from foundation 488 feet; from ground 474 feet.

ew York Steam Heating Co., 220 feet in height.

Pillar.

t a gate near Delhi is a wrought-iron pillar having diameters of 16.4 ins. at 22 in its height above ground and 12 ins. at its top. It is estimated from the re- of excavations at its base to be 60 feet in length or height and to weigh 17 . Its period of structure is assigned to the 3d or 4th century A.D.

Roofs.

and Railway Station, London.	240 ft.	Union Railway Station, Glasgow.	195 ft.
erial Riding-School, Moscow.	235 "	Grand Central Station, N. Y.....	200 "

Diameters of Domes.

Domes.	Feet.	Domes.	Feet.	Domes.	Feet.
tol, Washington	124.75	St. Paul's, London.	112	Midl'nd Rail'y, Lon.	240
gow W. Railw'y	198	St. Peter's, Rome..	139	Great North'n, Eng.	210

Lengths of Tunnels.

Tunnels.	Feet.	Tunnels.	Feet.	Tunnels.	Feet.
y..........	13 455	Gunpowder, Md...	36 500	Nerthe.........	15 153
Ridge......	4 280	Sutro............	20 028	Nochistongo....	21 659
ac..........	25 031	Semmering......	5 630	Riquivel........	18 623

Thames and Medway, 11 880 feet. Weehawken, 4000 feet.

nt Cenis 7.5 miles 242 yards, rises 1 in 45, and descends 1 in 2000.

Gothard Tunnels and Roads 9 miles 477 yards in length; tunnels 116 156.5 feet, ises 1 in 233 in whole length; 26.5 feet in width; 19 feet 10 ins. in height. mum grade 2.7 feet per 100. Schemnitz, 10.27 miles in length, 9 feet 10 ins. ight by 5.25 feet in width.

Miscellaneous.

tress Monroe, Old Point Comfort, Va.—Largest fortress.

graph Wire.—Span over river Kistnah between Bezorah and Sectanag eet in length.

r Park, Copenhagen.—4200 acres.

ord College, England.—Largest University; said to have been founde

edral. St. Peter's, Rome.—Width of front 216 feet; of the cross 251 feet; t 469.5 feet.

mer Great Eastern.—Of iron, 680 feet in length; 83 feet width of beam pth of hold; 22 927 tons; built at Millwall, England, 1857.

ese Wall.—25 feet at base; 15 at top; height, with a parapet of 1250 miles.

sian Well, Perth.—3050 feet in depth; temperature of wat *harge 18 000 gallons per day.*

Weights of Bells.

Bells.	Lbs.	Bells.	Lbs.	Bells.	Lbs.
Pekin	120 000	Oxford, "Great Tom," Eng.	17 024	St. Peter's, Rome.	18 000
Lewiston, Me.	10 233	Olmutz, Bohemia.	40 320	Vienna	40 200
Montreal, Can.	28 560	Rouen, France	40 000	Westm'ster, "Big Ben," England.	35 620
Moscow, Russia	443 772	St. Paul's, Eng.	42 000	York "	24 080
Erfurt, Saxony	30 800	St. Ivan's, Moscow	127 830	State House, Phila.	13 000
Notre Dame, Paris	28 670				

Rangoon, Burmah, 201 600 lbs.

Capacity of Principal Churches and Opera Houses.

Estimating a person to occupy an Area of 19.7 Ins. Square.

Churches.

St. Peter's	54 000	St. John, Lateran	22 900
Milan Cathedral	37 000	Notre Dame, Paris	21 000
St. Paul's, Rome	32 000	Pisa Cathedral	13 000
St. Paul's, London	25 600	St. Stephen's, Vienna	12 400
St. Petronio, Bologna	24 400	St. Dominic's, Bologna	12 000
Florence Cathedral	24 300	Tabernacle, London	7 000
Antwerp Cathedral	24 000	" Brooklyn	5 500
St. Sophia's, Constantinople	23 000	St. Mark's, Venice	7 000

Opera Houses and Theatres.

Carlo Felice, Genoa	2560	Teatro del Liceo, Barcelona	4000
Opera House, Munich	2370	Covent Garden, London	[illegible]
Alexander, St. Petersburg	2332	Opera House, Berlin	1636
San Carlos, Naples	2240	New York Academy	2526
Imperial, St. Petersburg	2160	Metropolitan Opera, N. Y.	3000
La Scala, Milan	2113	Philadelphia Academy	3124
Academy of Paris	2092	Chicago "	3000

Heights of Columns, Towers, Domes, Spires, etc.

Locations.		Feet.	Locations.		Feet.
CHIMNEYS.			TOWERS AND DOMES.		
Townsend's	Glasgow	474	Cathedral	Florence	390.5
St. Rollox	"	455.5	"	Magdeb'rg	339.9
Musprat's	Liverpool	406	"	Milan	438
Gas Works	Edinburgh	341.5	"	Petersburg	363
New England Glass Co.	Boston	230	Leaning	Pisa	188
Steam Heating Co.	New York.	220	Porcelain	China	200
			St. Mark's	Venice	328
COLUMNS.			St. Paul's	London	355.1
Alexander	St. Peters'g	175.			
Bunker Hill	Mass.	221	SPIRES.		
City	London	202	Cathedral	New York.	325
July	Paris	157	"	Strasburg	465.9
Napoleon	"	132	"	Antwerp	404.8
Nelson's	Dublin	134	Grace Church	New York.	216
Nelson's	London	171	Freiburg		410
Place Vendôme	Paris	136	Salisbury		450
Pompey's Pillar	Egypt	114	St. John's	New York.	210
Trajan	Rome	145	St. Paul's	"	200
Washington	Wash'gton	555	St. Mary's	Lübeck	404
York	London	138	Trinity Church	New York.	286
			Balustrade of Notre Dame	Paris	216
TOWERS AND DOMES.			Towers of ditto	"	232.9
Babel		680	Hôtel des Invalides	"	344
Balbec		500	St. Nicholas	Hamburg	473
Capitol	Wash'gton	287.5	St. Stephen	Vienna	443
…rs	Rome	469.5	Strasburg		468
…l	Cologne	524.9	Utrecht		464
[illegible]	Cremona	392	Votive Church	Vienna	[illegible]
[illegible]	Escurial	200			

reas of Lakes in Europe, Asia, and Africa.

ES.	Sq. Miles.	LAKES.	Sq. Miles.	LAKES.	Sq. Miles.
....	400	Dembia, Abyssinia.	13 000	Lough Neagh, Irel'd	80
ica......	11 600	Loch Lomond.....	27	Tonting, China....	1200

Lengths of Bridges.

GES.	Feet.	BRIDGES.	Feet.	BRIDGES.	Feet.
....	1710	Lyons...........	1560	Potomac.........	5300
....	1874	Menai...........	1050	Riga............	2600
....	2500	N. Y. and Brooklyn spans and approaches....	5989	St. Lawrence Riv'r	9144
s.......	995			Strasburg........	3390
....	3483			Vauxhall.........	860
....	950	Pont St. Esprit...	3060	Westminster.....	1223

Lengths of Spans of Bridges.

GES.	Feet.	BRIDGES.	Feet.	BRIDGES.	Feet.
....	460	Niag'a at the Falls	1268	Schuylkill.........	340
....	400	" at Queenstown...........	1040	Southwark.........	240
....	580			Wheeling.........	1010

Canals.

—Lake Erie to Albany 352 miles; Chesapeake and Ohio 307; Schuylkill
ware and Hudson 109; Rideau 132; London to Liverpool 265; Caledonia
ool and Leeds 127.5; Rhone to Rhine 203.

of Locks of Erie 240 tons, and of Welland 1500.

26.77 miles. Lake Erie to Montreal *via* Canal 70.5; Lake and River

l to Kingston.—Canal 120 miles; River 126.25. Suez, see page 183.

Breakwaters.

e.—Average depth of water 29.4 feet below low-water level; range of tide
Outer slope 45°; Inner slopes 1.5, 5, 3, and 1.3 to 1; length of base 172.12

th.—Outer slopes 1.75 to 1 from bottom to 7 feet 6 ins. below low-water
1 to low-water line; 16 to 1 to 4 feet 6 ins. above low-water line; 5 to 1
ter; Inner slope 1.5 to 1 above low-water line; 2 to 1 below low-water line.
f water at high tide 46.5 feet; at low tide 30 feet.
breakwater cased with large squared stones cramped together.

d.—Depth of high water 58 feet; of low water 51 feet. Outer slopes 1 to 1
om to 20 feet below low water; 2 to 1 to 12 feet below low water; 6 to 1
er line; 4 to 1 to high-water line; Inner slope 1.25 to 1.
breakwater, rubble, with crest wall of ashlar.

-Depth of high-water line 61 feet; of low-water line 42 feet.
' breakwater, concrete blocks faced with granite; batter 3 inches to the
ed up in each course.

les.—Depth of water 33 feet; Outer casing of beton 25.5 tons each; average
of casing from 14 to 20 feet; slope 1 to 1 from bottom to water line; 2.5
e water-line; all other slopes .33 to 1; Inner casing of first-class rubble
2 to 5 tons weight), about 12 feet thick; Hearting, second-class rubb
.5 to 2 tons weight), about 6 feet thick; Nucleus, of quarry rubbish.

—Depth of water 50 feet; rubble base carried up to 33 feet from surfac
remainder composed of large beton blocks 25.5 tons each; slopes of rul
; Outer slope of beton blocks 1.25 to 1; Inner slope of beton blocks 1 t

id (Suez Canal).—Concrete blocks, 10 cubic metres each, composed
lic lime to 13 of sand, mixed with sea water; 4 days in the mold and di
ths before being put in position. In some instances the composition
ks is .33 lime or cement to .66 sand and broken stone, about the size

or Block Filling.—Proportion of interstices to volume of breakwater
rst-class rubble of 2 to 5 tons, .25; second-class rubble of .5 to
rubble, *quarry chips, etc.*, .16; beton blocks, 15 to 25 tons,

For force of water, see Waves of the Sea, page 853.

Areas, Depths, and Heights of Great Northern Lakes of United States.

Lakes.	Length.	Breadth.	Mean Depth.	Height above Sea.	Area.
	Miles.	Miles.	Feet.	Feet.	Sq. Miles.
Erie	250	80	200	564	9 900
Huron	200	160	120	574	23 800
Michigan	360	109	900	587	22 000
Ontario	180	65	500	234	7 200
Superior *	400	160	288	635	32 000

* Greatest depth 5400 feet.

Elevation Above Tide-water at Albany. — Lake Erie 570.6 feet; Hudson River 2.46 feet.

Mean Depths and Areas of the Oceans and Seas.

(Herr Krümmel.)

	Fathoms.	Area Sq. Miles.		Fathoms.	Area Sq. Miles.
Atlantic	2013	29 514 275	Gulf of Mexico	1001	1 765 910
Archipelago	487	3 046 600	" " St. Lawrence	160	101 075
Azof	—	8 800	Indian	1829	28 369 595
Baltic Sea	36	159 690	Japan	1200	383 205
Black Sea	—	150 000	Mediterranean	729	1 109 236
Behring's Straits	550	864 555	North Sea	48	210 505
Caspian Sea	—	120 000	North Ice Sea	845	5 264 600
China (East) Sea	66	472 210	Persian Gulf	20	90 100
Dead Sea	—	370	Pacific	3887	60 343 690
English Channel, etc.	47	78 416	Red Sea	243	170 8[illegible]

Mean depth of Ocean surrounding land 1877 fathoms = 2.19 miles.

In his subsequent computations he estimates ocean area at 143 703 000 square miles and determines area of land to water as 1 to 2.75, and that mean height of land = 1377 feet, or one eighth that of Ocean.

Heights of Mountains, Volcanoes, and Passes above Level of Sea.

Mountains.	Feet.
EUROPE.	
Azores Pico	7 613
Barthélemy, France	7 365
Ben Lomond	3 240
Ben Nevis	4 380
Elbrus, Caucasus	17 776
Guadarama, Spain	8 520
Hecla	5 147
Ida	4 960
Jungfrau, Switz'd.	13 725
Mont Blanc	15 797
" Cenis	6 780
Mont d' Or, France	6 510
Mulahassen, Gren'a.	11 663
Nephin, Ireland	2 634
Olympus	6 510
Parnassus	6 000
Plynlimmon, Wales	2 463
The Cylinder, Pyr.	10 930
Wettorhorn	12 154
ASIA.	
[illegible]rarat	17 100
[illegible]	16 433
[illegible]	28 077
[illegible]	8 500
[illegible]	12 000

Mountains.	Feet.
Mount Everest (Himalaya, highest)	29 003
Mount Libanus	9 523
Petcha	15 000
Sinai	7 496
AFRICA.	
Atlas	10 400
Compass, Cape of Good Hope	10 000
Dianai Peak, St Helena	2 700
Kilimanjaro	20 000
Ruivo, Madeira	5 160
Teneriffe Peak	12 300
AMERICA.	
Aconcagua (highest in America)	23 910
Blue Mount, Jam'a.	8 000
Catskill	3 804
Chimborazo	21 441
Correde, Potosi	16 036
Crows' Nest, Highlands, N. Y.	1 370
Great Peak, New Mexico	19 788
Mauna Loa, Hawaii	13 805

Mountains.	Feet.
Mount Pitt	9 549
Mount Washington	6 426
Nevado de Sorata	25 248
Orizaba	18 879
Potosi	18 000
Sierra Nevada	15 700
Tahiti	10 895
White Mountains	6 230
VOLCANOES.	
Cotopaxi	18 887
Etna	10 874
Hecla	5 000
Popocatapetl	17 784
Sahama	22 350
St. Helen's, Oregon	13 320
Vesuvius	3 930
PASSES.	
Cordilleras	13 525 / 15 225
Mont Cenis	6 776
" Cervis	11 [illegible]
Pont d' Or	984
St. Bernard, Great	817
" Little	[illegible]
St. Gothard	[illegible]
Simplon	[illegible]

Dimensions of Canal Locks.—(*U. S.*)

Canal.	Length.	Breadth.	Depth.	Length of Canal.	Canal.	Length.	Breadth.	Depth.	Length of Canal.
	Feet.	Ft.	Ft.	Miles.		Feet.	Feet.	Feet.	Miles.
»emarle and Chesapeake..	220	40	6	14	Champlain.......	110	18	5	6C.75
ıck River, Crook'd L'ke, Chenango, Chemung, nd Genesee Valley.......	90	15	4	77 8, 97, 33, 113.75	Cayuga and Seneca......	110	18	7	24.75
					Delaware and Raritan......	220	24	7	43
					Dismal Swamp...	90	17.5	5.5	44
					Erie.............	110	18	7	352
					Falls of Ohio, Ky.	350	80	2–60	—
»sapeake and Delaware....	220	24	9	14	Oswego..........	110	18	4	38
					Welland, Canada..	270	45	14	28

ength of vessel that can be transported is somewhat less than lengths of locks.

Suez Canal.—Width 196 to 328 feet at surface, 72 at bottom, and 26 deep. gth 99 miles.

eights of obtained Elevations, and various Places and Points above the Sea.

Locations.	Feet.	Locations.	Feet.	Locations.	Feet.
ıcagua, Chili...	23 910	Geneva city.......	1 220	Mont Rosa, Alps...	15 155
isana, highest		Geneva Lake......	1 096	Mount Adams.....	5 930
tablished eleva-		Gibraltar..........	1 439	Mount Katahdin...	5 360
n (Farmhouse)..	13 434	Humboldt's highest		Mount Pitt........	9 549
»on (Gay Lussac)	22 900	elevation........	19 400	Mount Washington.	6 426
(Green, 1837)	27 000	Isthmus of Darien.	645	Paris, city.........	115
(Glaisher and		Jungfrau, Switz'd..	13 725	Pont d' Oro, Pyr's..	9 843
xwell).........	37 000	La Paz, Bolivia....	12 225	Posthouse, Ap., Peru	14 377
il, Quito, and	6 000	Laguna, Teneriffe...	2 000	Potosi, Bolivia.....	13 223
xico plains..	8 000	London, city.......	64	Quito.............	13 500
or's flight.....	29 500	Madrid...........	2 200	St. Bernard's Mon'y	8 040
»'s "	16 500	Mexico, city of.....	7 525	Vegetation........	17 000
»st, Himalaya.	29 003	Mont Blanc, Alps...	15 797	White Mountain...	6 230

Lengths of Rivers.

Rivers.	Miles.
EUROPE.	
»e............	1800
er............	1243
....	400
....	1035
....	780
ne...........	442
....	545
....	420
....	760
....	510
....	450
on..........	250
....	510
s...........	220
....	190
....	630
Russia......	2400
ASIA.	
....	2500
ses.........	1786

Rivers.	Miles.
Ganges...........	1514
Hoang Ho.........	3040
Indus............	1800
Jordan...........	176
Lena.............	2762
Tigris............	1160
Yenesei and Selenga...........	3580
Yang-Tse.........	3314
AFRICA.	
Gambia..........	700
Niger............	2400
Nile.............	4000
NORTH AMERICA.	
Arkansas.........	2070
Colorado.........	1050
Columbia.........	1200
Connecticut.......	410
Delaware.........	420
Hudson and Mohawk..........	325

Rivers.	Miles.
Kansas...........	1400
La Platte.........	850
Mackenzie........	2440
Mississippi.......	3160
Missouri.........	3030
Ohio and Allegheny	1480
Potomac.........	420
Red.............	1520
Rio Bravo........	23
Rio Grande.......	1
St. Lawrence......	2
Susquehanna......	
Tennessee........	
SOUTH AM	
Amazon..	
Essequibo	
Magdalena	
Orinoco...	
Platte....	
Rio Made	
Rio Negro	
Uruguay..	

Large Trees in California.

"*Keystone State.*"—Calavera Grove, is 325 feet in height.

"*Father of the Forest.*"—Felled, is 385 feet in length, and a man on horseback can ride erect 90 feet inside of its trunk.

"*Mother of the Forest.*"—Is 315 feet in height, 84 feet in circumference (26.75 feet in diameter) inside of its bark, and is computed to contain 537 000 feet of sound 1 inch lumber.

Sea Depths.

	Feet.		Feet.		Feet.
Baltic Sea	120	Coast of Spain	6 000	Off Cape Canaveral.	2400
Adriatic	130	West of St. Helena.	27 000	" Charleston	4200
English Channel	300	Tortugas to Cuba	4 200	" Cape Hatteras	3120
Straits of Gibraltar.	100	Gulf of Florida	3 720	" Cape Henry	4200
Eastward of "	3000	Off Cape Florida	1 950	" Sandy Hook	2400

Estimated depth of Atlantic.................................. 26 000 feet.
" " Pacific.................................. 29 000 "

250 miles off Cape Cod, no bottom at 7800 feet.

Cascades and Waterfalls.

Location.	Feet.	Location.	Feet.	Location.	Feet.
Arve, Savoy	1600	Genesee, N. Y.	100	Niagara	164
Cascade, Alps	2400	Lidford, England	100	Great Fall	152
Cataracts of the Nile.	30, 34, 40	Lulea, Sweden	600	Passaic	74
		Mohawk	68	Potomac	74
Chachia, Asia	362	Missouri	50, 80, 94	Ribbon, Yosemite Valley	3300
Foyers, Scotland	197			Ruican, Norway	800
Garisha, India	1000	Montmorenci	250	Staubbach, Switz'd.	798
Gavarny, Pyrenees	1260	Nant d'Apresias	800	Tendon, France	125

Yosemite Valley............2600 feet.

Expansion and Contraction of Building Stones for each Degree of Temperature. (*Lieut. W. H. C Bartlett, U. S. E.*)

	For One Inch.		For One Inch.
Granite	.000 004 825	Sandstone	.000 009 532
Marble	.000 005 668	Whitepine	.000 002 55

Resistance of Stones, etc., to the Effects of Freezing.

Various experiments show that the power of stones, etc., to resist effects of freezing is a fair exponent of that to resist compression.

Magnetic Bearings of New York.

The Avenues of the City of New York bear 28° 50′ 30″ East of North.

Filters for Waterworks.

1 square yard of filter for each 840 U. S. and 700 Imp'l gallons in 24 hours; formed of 2.5 feet of fine sand or gravel and 6 inches of common sand or shells.

Led off by perforated pipes laid in lowest stratum.

Distances between New York, Boston, Philadelphia, Baltimore, and Western Cities of U. S.

Assuming Boston as standard, New York averages 12 per cent. nearer to these cities, Philadelphia 18 per cent., and Baltimore 22 per cent.

Between New York and Chicago the line of the Pennsylvania Railroad is 47 miles shorter than that by the Erie and its connections, 50 miles shorter than that by the N. Y. Central and Hudson River and its connections, and 114 miles shorter than that by the Baltimore and Ohio and its connections.

For Distances between these and other cities of the U. S., see page 88.

Weather-foretelling Plants. (*Hanneman.*)

ain is imminent.—Chickweed,* *Stellaria media;* its flowers droop not open. Crowfoot anemone, *Anemone ranunculoides;* its blossoms Bladder Ketmia, *Hibiscus trionum;* its blossoms do not open. Thistle, *s acaulis;* its flowers close. Clover, *Trifolium pratense*, and its allied and Whitlow grass, *Draba verna;* all droop their leaves. Nipple-*ampsana communis;* its blossoms will not close for the night. Yel-dstraw, *Galium verum;* it swells, and exhales strongly; and Birch, *alba*, exhales and scents the air.

:ations of Rain.—Marigold, *Calendula pluvialis;* when its flowers do n by 7 A. M. Hog Thistle, *Sonchus arvensis* and *oleraceus;* when its is open.

of short duration.—Chickweed, *Stellaria media;* if its leaves open tially.

'oudy.—Wind-flower, or Wood Anemone, *Anemone memorasa;* its droop.

iination of Rain.—Clover, *Trifolium pratense;* if it contracts its Birdweed and Pimpernel, *Convolvulus* and *Anagallis arvensis;* if read their leaves.

'orm Weather.—Marigold, *Calendula pluvialis;* if its flowers open early A. M. and remain open until 4 P. M.

· Weather.—Wind-flower, or Wood Anemone, *Anemone memorasa;* ars its flowers erect. Hog Thistle, *Sonchus arvensis* and *oleraceus;* eads of its blossoms close at and remain closed during the night.

:ment and Antidotes to Severe Ordinary Poisons.

Antidotes in very small doses.

'oform and Ether.—Cold affusions on head and neck, and ammonia :ils. *Antidote.*—Camphor, petroleum, sulphur.

'stools.—(Inedible mushroom). *Antidote.*—Same as for chloroform.

sic or *Fly Powder.*—Emetic; after free vomiting give calcined mag-eely. If poison has passed out of stomach, give castor oil. *ote.*—Camphor, nux vomica, ipecacuanha.

ate of Lead (Sugar of lead).—Mustard emetic, followed by salts, lraughts of milk with white of eggs. *ote.*—Alum, sulphuric acid alike to lemonade, belladonna, strychnine.

sive Sublimate (Bug poison).—White of eggs in 1 quart of cold give cupful every two minutes. Induce vomiting without aid of . Soapsuds and wheat flour is a substitute for white of eggs. *ote.*—Nitric acid, camphor, opium, sulphate of zinc.

phorus Matches.—*Rat Paste.*—Two teaspoonfuls of calcined magne-owed by mucilaginous drinks. *Antidote.*—Camphor, coffee, nux vomica.

onic Acid (Charcoal fumes), *Chlorine, Nitrous Oxide*, or *Ordinary* Fresh air, artificial respiration, ammonia, ether, or vapor of hot water. *ote.*—Camphor, coffee, nux vomica.

:donna (Nightshade).—Emetic and stomach pump, morphine and coffee. *Antidote.*—Camphor.

m.—Stomach pump or emetic of sulphate of zinc, 20 or 30 grains, or l or salt. Keep patient in motion. Cold water to head and chest. *ote.*—Strong coffee freely and by injection, camphor, ether, and nux vomica.

hnine (Nux vomica).—Stomach pump or emetic, · ·. cam-imal charcoal, lard, or fat. *ote.*—Wine, coffee, camphor, opium freely, and alcohol

'able Poisons.—As a rule, an emetic of mustard ı vater.

---

* *Spreads its leaves about 9 A. M., and they remain open un.*

Veterinary.

Horses.—*Cathartic Ball.*—Cape Aloes, 6 to 10 drs.; Castile Soap, 1 dr.; Spirit of Wine, 1 dr.; Sirup to form a ball. If Calomel is required, add from 20 to grains. During its operation, feed upon mashes and give plenty of water.

Cattle.—*Cathartic.*—Cape Aloes, 4 drs. to 1 oz.; Epsom Salts, 4 to 6 oz.; Ginger, 3 drs. Mix, and give in a quart of gruel. For Calves, one third will be sufficient.

Horses and Cattle.—*Tonic.*—Sulphate of Copper, 1 oz. to 12 drs.; .5 oz. Mix, and divide into 8 powders, and give one or two daily in food.

Cordial.—Opium, 1 dr.; Ginger, 2 drs.; Allspice, 3 drs., and Caraway Seeds, drs., all powdered. Make into a ball with sirup, or give as a drench in gruel.

Cordial Astringent Drench, for Diarrhœa, Purging, or Scouring.—Tincture of Opium, .5 oz.; Allspice, 2.5 drs.; powdered Caraway, .5 oz.; Catechu Powder, 2 drs.; strong Ale or Gruel, 1 pint. Give every morning till purging ceases. For Sheep .25 this quantity.

Alterative.—Ethiop's Mineral, .5 oz.; Cream of Tartar, 1 oz.; Nitre, 2 drs. Divide into from 16 to 24 doses, one morning and evening in all cutaneous diseases.

Diuretic Ball.—Hard Soap and Turpentine, each 4 drs.; Oil of Juniper, 20 drops; and powdered Resin to form a ball.

For Dropsy, Water Farcy, Broken Wind, or Febrile Diseases, add to above, Allspice and Ginger, each 2 drs. Divide into 4 balls, and give one morning and evening.

Alterative or Condition Powder.—Resin and Nitre, each 2 oz.; levigated Antimony, 1 oz. Mix for 8 or 10 doses, and give one morning and evening. When given to Cattle, add Glauber Salts, 1 lb.

Fever Ball.—Cape Aloes, 2 oz.; Nitre, 4 oz.; Sirup to form a mass. Divide into 12 balls, and give one morning and evening until bowels are relaxed; then give Alterative Powder or Worm Ball.

Hoof Ointment.—Tar and Tallow, each 1 lb.; Turpentine .5 lb. Melt and mix.

Dogs.—*Cathartic.*—Cape Aloes, .5 dr. to 1 oz.; Calomel, 2 to 3 grs.; Oil of Caraway, 6 drops; Sirup to form a ball. Repeat every 5 hours till it operates.

Emetic.—2 to 4 grs. of Tartar Emetic in a meat ball, or a teaspoonful or two of common salt. Give twice a week if required.

Distemper Powder.—Antimonial Powder, 2, 3, or 4 grs.; Nitre, 5, 10, or 15 grs.; powdered Ipecacuanha, 2, 3, or 4 grs. Make into a ball, and give two or three times a day. If there is much cough, add from .5 gr. to 1 gr. of Digitalis, and every 3 or 4 days give an Emetic.

Mange Ointment.—Powdered Aloes, 2 drs.; White Hellebore, 4 drs.; Sulphur, 4 oz.; Lard, 6 oz.—*Red Mange,* add 1 oz. of Mercurial Ointment, and apply a muzzle.

NOTE.—Physic, except in urgent cases, should be given in morning, and upon an empty stomach; and, if required to be repeated, there should be an interval of several days between each dose.

Age of Horses.

To Ascertain a Horse's Age.

A foal of six months has six grinders in each jaw, three in each side, and also six nippers or front teeth, with a cavity in each.

At age of one year, cavities in front teeth begin to decrease, and he has four grinders upon each side, one of permanent and remainder of milk set.

At age of two years he loses the first milk grinders above and below, and front teeth have their cavities filled up alike to teeth of horses of eight years of age.

At age of three years, or two and a half, he casts his two front uppers, and in a short time after the two next.

At four, grinders are six upon each side; and, about four and a half, his nippers are permanent by replacing of remaining two corner teeth; tushes then appear, and he is no longer a colt.

At five, a horse has his tushes, and there is a black-colored cavity in centre of all ... lower nippers.

...ack cavity is obliterated in the two front lower nippers.

...ies of next two are filled up, and tushes blunted; and at eight ... teeth. Horse may now be said to be aged. Cavities in ... not obliterated till horse is about ten years old, after which ...nd. and nippers project and change their surface.

stances between Principal Cities of East and West.

In Miles.

Cities.	Boston.	New York.	Phila-delphia.	Balti-more.	Cities.	Boston.	New York.	Phila-delphia.	Balti-more.
lington, Ia.	1216	1106	1030	995	Louisville.....	1161	870	794	706
'ago.......	1009	900	823	802	Memphis......	1438	1247	1171	1083
:nnati....	927	743	667	576	Milwaukee....	998	947	908	887
eland.....	671	580	504	483	Omaha........	1503	1393	1317	1294
mbus, O..	807	623	547	512	St. Joseph.....	1478	1356	1280	1223
oit.......	724	673	682	661	St. Louis......	1212	1050	973	917
anapolis..	951	810	735	700	St. Paul.......	1418	1308	1232	1211
sas City...	1487	1324	1248	1192	Toledo........	784	693	617	596

Population of Principal Cities (1882).

lon.........	3 832 440	Marseilles........	357 530	Stockholm.......	168 770
;...........	2 225 910	St. Louis........	350 518	Brussels..........	161 820
in..........	1 222 500	Warsaw..........	339 400	Cleveland........	160 146
York......	1 206 299	Baltimore........	332 313	Pittsburgh........	156 389
na.........	1 103 110	Milan............	321 440	Buffalo..........	155 134
etersburg...	876 570	Amsterdam.......	317 010	Antwerp..........	150 650
idelphia....	847 170	Rome............	300 470	Washington......	147 293
ow.........	611 970	Lisbon...........	246 300	Cologne..........	144 770
tantinople..	600 000	Palermo..........	244 990	Frankfort........	136 820
igo.........	583 185	Copenhagen......	234 850	Newark..........	136 508
klyn.......	566 663	San Francisco....	233 959	Venice...........	132 830
burg.......	410 120	Munich..........	230 200	Louisville........	123 758
es..........	403 110	Cincinnati........	225 139	Jersey City.......	120 722
s..........	372 890	Bucharest........	221 800	Detroit...........	116 340
id..........	367 280	Dresden..........	220 820	Milwaukee........	115 587
in..........	362 839	New Orleans.....	216 190	Providence.......	104 857
-Pesth.....	360 580	Florence.........	169 000	Rouen...........	104 010

Treatment of Drowning Persons.

ractice adopted by Board of Health, New York.

ce patient face downward, with one of his wrists under his forehead. Cleanse outh. If he does not breathe, turn him on his back with shoulders raised on port. Grasp tongue gently but firmly with fingers covered with end of a handief or cloth, draw it out beyond lips, and retain it in this position.

Produce and Imitate Movements of Breathing.—Raise patient's extended arms rd to sides of his head, pull them steadily, firmly, slowly, outwards. Turn elbows by patient's sides, and bring arms closely and firmly across pit of ch, and press them and sides and front of chest gently but strongly for a mo- then quickly begin to repeat first movement.
these two movements be made very deliberately and without ceasing until t breathes, and let the two movements be repeated about twelve or fifteen in a minute, but not more rapidly, bearing in mind that to thoroughly fill the with air is the object of first or upward and outward movement, and to expel ch air as practicable is object of second or downward motion and pressure. rtificial respiration should be maintained for forty minutes or more, when the t appears not to breathe; and after natural breathing begins, let same motion y gently continued, and give proper stimulants in intervals.

at Else is to be Done, and What is Not to be Done, while the Movements are Made.—If help and blankets are at hand, have body stripped, wrapped in ts, but not allow movements to be stopped. Briskly rub feet and legs, pressem firmly and rubbing upward, while the movements of the arms and chest progress. Apply hartshorn, or like stimulus, or a feather within the nostrils onally, and sprinkle or lightly dash cold water upon face and neck. The id feet should be rubbed and wrapped in hot blankets, if blue or cold. er is cold.

at to Do when Patient Begins to Breathe.—Give stimulants by teaspoonf e times a minute, until beating of pulse can be felt at wrist, but be t give more of stimulant than is necessary. Warmth should be ke d legs, and as soon as patient breathes naturally, let him be carefully r aclosure, and placed in bed, under medical care.

MISCELLANEOUS ELEMENTS.

Earth.

Polar diameter 7899.3 *miles*. Mean density or specific gravity of mass 5.672. Mass 5 272 600 000 000 000 000 000 *tons*. Apparent diameter as seen from Sun 17 seconds.

Sun.

Heat of Sun equal to 322 794 thermal units per minute for each sq. foot of photosphere or solar surface.

Diameter of Sun 882 000 miles, tangential velocity 1.25 miles per second or 4.4 times greater than that of the Earth.

Distance from Earth 91.5 to 92 millions of miles.

Mason and Dixon's Line.

39° 43′ 26.3″ N. mean latitude. 68.895 miles.

Area and Population. (*Behm and Wagner.*)

Divisions.	Area.	Population.	Divisions.	Area.	Population.
	Sq. Miles.			Sq. Miles.	
America........	14 491 000	95 495 500	Oceanica........	4 500 000	4 031 000
Europe.........	3 760 000	315 929 000	Greenland, Iceland		82 000
Asia............	16 313 000	834 707 000			
Africa..........	10 936 000	205 679 000	Total......	50 000 000	1 455 923 500

Countries.

Austria, Hungary	38 000 000	Germany......	43 900 000	India, British ..	240 298 000
China..........	434 626 000	Great Britain..	34 000 000	Canada.........	3 839 000
France.........	37 000 000	Russia.......	66 000 000	Mexico.........	9 485 000
		Territories ...	22 000 000	Brazil	11 108 000
United States....	50 000 000	Turkey.......	8 866 000		
Indians	300 000	" in Asia..	16 320 000		

About one thirtieth of whole population are born every year, and nearly an equal number die in same time; making about one birth and one death per second.

Earlier authority estimated population at 1 288 000 000, divided as follows:

Caucasians.....	360 000 000	Malays and Indo-Amer's	177 000 000	Mohammedans.	190 000 000
Mongolians	552 000 000			Pagans.........	300 000 000
Ethiopians.....	190 000 000	Protestants....	80 000 000	Catholics, Rom. & Greek	250 000 000
Asiatics........	60 000 000	Israelites......	5 000 000		

Descent of Western Rivers.

Slope of rivers flowing into Mississippi from East is about 3 inches per mile; and from West 6 inches.

Mean descent of Ohio River from Pittsburgh to Mississippi, 975 miles, is about 5.2 inches per mile; and that of Mississippi to Gulf of Mexico, 1180 miles, about 2.8 inches.

Transmission of Horse Power.

Largest, and perhaps most successful, wire rope transmission is one at Schaffhausen, at Falls of the Rhine. Here, power of a number of turbines, amounting to over 600 IP, is conveyed across the stream, and thence a mile to a town, where it is distributed and utilized.

At mines of Falun, Sweden, a power of over 100 horses is transmitted in like manner for a distance of three miles.

Acids.

Acetic Acid (Vinegar), acid of *Malt beer*, etc. *Tartaric Acid*, acid of *Grape wine*. *Lactic Acid*, acid of *Milk*, *Millet beer*, and *Cider*.

Manures.

Relative Fertilizing Properties of Various Manures.

Peruvian Guano	1	Horse	.048	Farm-yard.....	.0298
Human, mixed......	.069	Swine..........	.044	Cow............	.0259

Or, 1 lb. guano = 14.5 human, 21 horse, 22.5 swine, 33.5 farm-yard, and 38.5 cow.

Relative Value, Covered and Uncovered, on an Acre of Ground.

Covered ....11 tons 1665 lbs. potatoes, 61 lbs. wheat, 215 lbs. [illegible]
Unco[illegible] .... 7 " 1397 " " 61.5 " " 156 "

Yield of Oil of Several Seeds.

	Per Cent.		Per Cent.		Per Cent.		Per Cent.		Per Cent.
ppy..	56 to 63	Castor..	25	Sunflower.	15	Hemp.	14 to 25	Linseed.	11 to 22

Thickness of Walls of Buildings. (*English.*) (*Molesworth.*)

Outer Walls.	Maximum Height of Wall.	Width of Footings.	Minimum Width of Walls. Ground Floor.	1st Floor.	2d Floor.	3d Floor.	4th Floor.	5th Floor.	6th Floor.
	Feet.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
t class dwelling.	85	38.5	21.5	21.5	17.5	17.5	17.5	13	13
" "	70	30.5	17.5	17.5	17.5	13	13	13	—
" "	52	30.5	17.5	13	13	13	13		—
h " "	38	21.5	13	13	8.5	8.5	—		—
Party Walls.									
t class dwelling.	85	38.5	21.5	21.5	17.5	17.5	17.5	13	13
" "	70	30.5	17.5	17.5	17.5	13	13	13	—
" "	52	30.5	17.5	13	13	13	8.5		—
" "	38	21.5	13	8.5	8.5	8.5	—		—

f walls are more than 70 feet in length, those of lower stories must be widened half a brick.

Warehouses 1st Class.

	Minimum Width of Wall.
	Ins.
r a height of 36 feet from opmost ceiling	17.5
: a height of 40 feet lower..	21.5
" " 24 feet lower..	26
· footings	43.5

Warehouses 2d Class.

	Minimum Width of Wall.
	Ins.
For a height of 22 feet below topmost ceiling	13
For a height of 36 feet lower..	17.5
" " 8 feet lower..	21.5
For footings	34.5

3d Class.

a height of 28 feet below ɔpmost ceiling	13
a height of 16 feet lower..	17.5
footings	30.5

4th Class.

For a height of 9 feet below topmost ceiling	8.5
For a height of 13 feet below..	13
For footings	21.5

Wooden Roofs. (*English.*)

ın ɜet.	Principal Beam.	Tie Beam.	King Posts.	Queen Posts.	Small Queens.	Straining Beam.	Struts.
[illegible]	4 × 4	9 × 4	4 × 4	—	—	—	3 × 3
[illegible]	5 × 4	10 × 5	5 × 5	—	—	—	5 × 3
[illegible]	6 × 4	11 × 6	6 × 6	—	—	—	6 × 3
[illegible]	5 × 4	11 × 4	—	4 × 4	—	7 × 4	4 × 2
[illegible]	6 × 5	13 × 6	—	6 × 6	—	7 × 6	5 × 3
[illegible]	8 × 6	13 × 8	—	8 × 8	8 × 4	9 × 6	5 × 3
[illegible]	8 × 7	14 × 9	—	9 × 8	9 × 4	10 × 6	5.5 × 3
[illegible]	8 × 8	15 × 10	—	10 × 8	10 × 4	11 × 6	6 × 3

ineral Constituents absorbed or removed from an Acre of Soil by several Crops. (*Johnson.*)

rops.	Wheat, 25 bushels.	Barley, 40 bushels.	Turnips, 20 tons.	Hay, 1.5 tons.	Crops.	Wheat, 25 bushels.	Barley, 40 bushels.	Turnips, 20 tons.	Hay, 1.5 tons.
	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
sa......	29.6	17.5	47.1	38.2	Sulphuric Acid...	10.6	2·	13.3	9.2
....	3	5.2	8.2	12					
....	12.9	17	29.9	44·	Chlorine.....	2	·6	3.6	4.1
esia....	10.6	9.2	19.7	7·	Silica........	118.1		2	78.2
of Iron.	2.6	2.1	7.1	.6	Alumina.....	—			—
hhoric d....	20.6	25.8	46.3	15.1	Total....	210			

Average Quantity of Tannin in Several Substances.

(*Morfit.*)

	Per Cent.		Per Cent.		Per Cent.
Catechu.		*Oak.*		*Sumac.*	
Bombay........	55	Young, inner b'k	15.2	Sicily and Malaga	16
Bengal.........	44	" entire b'k.	6	Virginia........	10
Kino.............	75	" spring-cut bark	22	Carolina........	5
Nutgalls.		" root bark.	8.9	*Willow.*	
Aleppo.........	65	*Chestnut.*		Inner bark......	16
Chinese.........	69	Amer. rose, bark	8	Weeping........	16
Oak.		Horse, "	2	*Sycamore* bark....	16
Old, inner bark	14.2 / 21	*Sassafras*, root bark	58	*Tan shrub* "	13
				Cherry-tree.......	24

Alder bark................ 36 per cent.

To Convert Chemical Formulæ into a Mathematical Expression.

RULE.—Multiply together equivalent and exponent of each substance, and product will give proportion in compound by weight. Divide 1000 by sum of their products, and multiply this quotient by each of these products, and products will give respective proportion of each part by weight in 1000.

EXAMPLE.—Chemical formula for alcohol is $C_4 H_6 O_2$. Required their proportional parts by weight in 1000?

$$\left.\begin{array}{ll} C_4 \text{ Carbon} & = 6.1 \times 4 = 24.4 \\ H_6 \text{ Hydrogen} & = 1 \times 6 = 6 \\ O_2 \text{ Oxygen} & = 8 \times 2 = 16 \end{array}\right\} \times 21.55 \left\{\begin{array}{l} 525.82 \\ 129.3 \\ 344.8 \end{array}\right\} \text{by weight.}$$

$$1000 \div 46.4 = 21.55 \qquad 999.92$$

Elementary Bodies, with their Symbols and Equivalents.

Body.	Symb.	Equiv.	Body.	Symb.	Equiv.	Body.	Symb.	Equiv.
Aluminium...	Al	13.7	Gold.........	Au	196.6	Platinum....	Pt	98.8
Antimony....	Sb	64.6	Hydrogen....	H	1	Potassium...	K	39.2
Arsenic......	As	37.7	Iodine.......	I	126.5	Rhodium....	R	52.2
Barium......	Ba	68.6	Iridium......	Ir	98.5	Selenium....	Se	40
Bismuth.....	Bi	71.5	Iron.........	Fe	28	Silicon.......	Si	22
Boron.......	B	11	Lead........	Pb	103.7	Silver........	Ag	108.3
Bromine.....	Br	78.4	Lithium.....	L	7	Sodium......	Na	23.5
Cadmium....	Cd	55.8	Magnesium..	Mg	12.7	Strontium....	Sr	43.8
Calcium......	Ca	20.5	Manganese...	Mn	26	Sulphur......	S	16.1
Carbon......	C	6.1	Mercury.....	Hg	200	Tellurium....	Te	64.2
Chlorine.....	Cl	35.5	Molybdenum.	Mo	47.9	Tin...........	Sn	58.9
Chromium...	Cr	26.2	Nickel.......	Ni	29.5	Titanium....	Ti	24.5
Cobalt.......	Co	29.5	Nitrogen.....	N	14.2	Tungsten....	W	92
Columbium..	Ta	184.8	Osmium.....	Os	99.7	Uranium....	U	60
Copper......	Cu	31.7	Oxygen......	O	8	Yttrium.....	Y	32
Fluorine.....	F	18.7	Palladium....	Pd	53.3	Zinc..........	Zn	32.3
Glucinum....	G	6.9	Phosphorus..	P	15.9	Zirconium...	Zr	34

Analysis of certain Organic Substances by Weight.

Body.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Body.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Albumen.......	52.9	7.5	23.9	15.7	Morphine......	72.3	6.4	16.3	5
Alcohol........	52.7	12.9	34.4	—	Narcotine......	65	5.5	27	2.5
Atmospheric air	—	—	77	23	Oil, Castor......	74	10.3	15.7	—
Camphor......	73.4	10.7	15.6	.3	Linseed....	76	11.3	12.7	—
Caoutchouc....	87.2	12.8	—	—	Spermaceti.	78	11.8	10.2	—
[illegible].......	59.8	7.4	11.4	21.4	Quinine........	75.8	7.5	8.6	8.1
[illegible].....	53.4	7	19.7	19.9	Starch.........	44.2	6.	49.1	—
[illegible]	47.0	7.9	27.2	17	Strychnine.....	76.4	6.7	11.1	5.8
[illegible]	[illegible]	[illegible]	50.9	—	Sugar..........	42.2	6.6	51.2	—
[illegible]	[illegible]	[illegible]	7.6	1.8	Tannin.........	52.6	3.8	43.6	—
[illegible]	[illegible]	[illegible]	.8	—	Urea...........	18.9	9.7	26.2	[illegible]

ilution Per Cent. Necessary to Reduce Spirituous Liquors.

'ater to be added to 100 volumes of spirit when of following strength:

ngth ired.	90	85	80	75	70	65	60	55	50
cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
5	5.9	—	—	—	—	—	—	—	—
o	12.5	6.3	—	—	—	—	—	—	—
'5	20	13.3	6.7	—	—	—	—	—	—
'o	28.6	21.4	14.3	7.1	—	—	—	—	—
5	38.5	30.8	23.1	15.4	7.7	—	—	—	—
o	50	41.7	33.3	25	16.7	8.3	—	—	—
5	63.6	54.5	45.5	36.4	27.4	18.2	9.1	—	—
o	80	70	60	50	40	30	20	10	—
o	125	112.5	100	87.5	75	62.5	50	37.5	25
o	200	183.3	166.7	150	133.3	116.7	100	83.3	66.7

LUSTRATION.—100 volumes of spirituous liquor having 90 per cent. of spirit cons: alcohol 90, water 10, = 100.
o reduce it to 30 per cent. there is required 200 volumes of water.

Hence $200 + 10 = 210$, and $\frac{90}{210} = \frac{30}{70} = \frac{30 \text{ spirit,}}{70 \text{ water,}}$ or 30 *per cent.*

Proportion of Alcohol Per Cent.

In 100 Parts of Spirit, by Weight or Volume, at 60°.

hol.	Specific Gravity.	Alcohol.	Specific Gravity.	Alcohol.	Specific Gravity.	Alcohol.	Specific Gravity.
o	1	20	.972	50	.918	80	.848
5	.991	30	.958	60	.896	90	.823
o	.984	40	.94	70	.872	100	.794

In 100 Parts of Alcohol and Water, by Weight, at 60°.

hol.	Specific Gravity.	Alcohol.	Specific Gravity.	Alcohol.	Specific Gravity.	Alcohol.	Specific Gravity.
	1	1.99	.996	5.01	.991	7.99	.987
3	.999	3.02	.994	6.02	.99	9.05	.985
2	.998	4.02	.993	7.02	.988	10.07	.984

ides of Atlantic and Pacific Oceans at Isthmus of Panama. (*Totten.*)

lantic, Navy Bay.—Highest tide 1.5 *feet;* lowest .63 *feet.*

cific, Panama Bay.—Highest tide 17.72 to 21.3 *feet;* lowest 9.7 *feet.*

Areas of U. S. Coal Fields.

State.	Sq. Miles.	State.	Sq. Miles.	State.	Sq. Miles.
is..........	44 000	Ohio............	11 900	Tennessee.......	4300
nia.........	21 000	Indiana.........	7 700	Alabama.........	3400
sylvania*...	15 437	Missouri†........	6 000	Maryland........	550
ucky........	13 500	Michigan†.......	5 000	Georgia..........	150

* Bituminous and Anthracite. † Anthracite.

Extremes of Heat in Various Countries.

nd.... 96°	Denmark / Sweden / Norway .. 99.5°	Greece...... 105°	Egypt...... 116.1°
e..... 106.5°		Italy........ 104°	Africa...... 133.4°
nd / am . 102°		Spain....... 102°	Asia....... 120°
	Russia...... 102°	Tunis....... 112.5°	Suez....... 126.5°

Germany......103° | Manilla......113.5° | N. America....102°

remes of temperature upon the Earth 240°.

Extremes of Cold in Various Cou

nd...— 5°	Denmark / Sweden / Norway —67°	France....—24°	Italy
/ —12°		Russia ....—46°	Fort
		Germany..—32°	Sem.

Mean Temperatures of Various Localities.

London	51°	Rome	60°	Poles	−13°	Polar Regions	36°
Edinburgh	41°	Equator	82°	Torrid Zone	75°	Globe	50°

Line of Perpetual Congelation, or Snow Line.

Latitude.	Height.	Latitude.	Height.	Latitude.	Height.	Latitude.	Height.
°	Feet.	°	Feet.	°	Feet.	°	Feet.
10	14 764	30	11 484	50	6334	70	1278
15	14 760	35	10 287	55	5020	75	1016
20	13 478	40	9 000	60	3818	80	451
25	12 557	45	7 670	65	2230	85	327

At the Equator it is 15 260 feet; at the Alps 8120 feet; and in Iceland 3084 feet. At Polar Regions ice is constant at surface of the Earth.

Limits of Vegetation in Temperate Zone.

The Vine ceases to grow at about 2300 feet above level of the sea, Indian Corn at 2800, Oak at 3350, Walnut at 3600, Ash at 4800, Yellow Pine at 6200, and Fir at 6700.

Periods of Gestation and Number of Young.

	Weeks.	No.		Weeks.	No.		Weeks.	No.		Weeks.	No.
Elephant	100	1	Cow	41	1	Sheep	21	2	Dog	9	6
Horse	43 / 50	1	Buffalo	40	1	Goat	22	2	Fox	9	5
			Stag	36	1	Beaver	17	3	Cat	8	6
Camel	45	1	Bear	30	2	Pig	17	12	Rat	5	8
Ass	43	1	Deer	24	2	Wolf	10	5	Squirrel	4	6
			Rabbit	4	6	Guinea Pig	3	3			

Periods of Incubation of Birds.

Swan, 42 days; Parrot, 40 days; Goose and Pheasant, 35 days; Duck, Turkey, and Peafowl, 28 days; Hens of all gallinaceous birds, 21 days; Pigeon and Canary, 14 days. Temperature of incubation is 104°.

Ages of Animals, etc.

Whale, estimated 1000 years; Elephant, 400; Swan, 300; Camel, 100; Eagle, 100; Raven, 100; Tortoise, 100 to ——; Lion, 70; Dolphin, 30; Horse, 30; Porpoise, 30; Bear, 20; Cow, 20; Deer, 20; Rhinoceros, 20; Swine, 20; Wolf, 20; Cat, 15; Fox, 15; Dog, 15; Sheep, 10; Hare, Rabbit, and Squirrel, 7.

Relative Weights of Brain.

Man, 154.33; Mammifers, 29.88; Birds, 26.22; Reptiles, 4.2; Fish, 1.

Buoyancy of Casks.

Buoyancy of a cask in fresh water in lbs. = 11.97 times volume of it in U. S. gallons and 10 times in Imperial gallons, less weight of cask.

Transportation of Horses and Cattle.

Space required on board of a Marine Transport is: for Horses, 30 ins. by 9 feet; Beeves, 32 ins. by 9 feet. Provender required *per diem* is: for Horses, Hay, 15 lbs.; Oats, 6 quarts; Water, 4 gallons. Beeves, Hay, 18 lbs.; Water, 6 gallons.

Rock and Earth Excavation and Embankment.

Number of Cube Feet of various Earths in a Ton.

Loose Earth	24	Clay	18.6	Clay with Gravel	14.4
[illegible]	18.6	Earth with Gravel	17.8	Common Soil	15.6

Earth and Sand in embankment exceeds that in a primary ex[illegible]g proportions:

Rock, ballast	1.2	Clay	.111
[illegible]nd	.143	Gravel	.09

out .12.

Hills or Plants in an Area of One Acre.

From 1 to 40 feet apart from centres.

...art.	No.	Feet apart.	No.	Feet apart.	No.	Feet apart.	No.
	43 560	5	1742	9	538	16	171
	19 360	5.5	1440	9.5	482	17	151
	10 890	6	1210	10	435	18	135
	6 969	6.5	1031	10.5	361	20	108
	4 840	7	889	12	302	25	69
	3 556	7.5	775	13	258	30	48
	2 722	8	680	14	223	35	35
	2 151	8.5	692	15	193	40	27

...mber of several Seeds in a Bushel, and Number per Square Foot per Acre.

	No.	Sq. Foot.		No.	Sq. Foot.
...thy........	41 823 360	960	Rye............	888 390	20.4
...r..........	16 400 960	376	Wheat..........	556 290	12.8

Volumes.

...manent gases, as air, etc., are diminished in their volume in a ratio direct ... that of pressure applied to them. With vapor, as steam, etc., this rule is ...l in consequence of presence of the temperature of vaporization.

Minerals.

Relative Hardness of some Minerals.

.... 1	Barytes....... 3.5	Opal.......... 6	Emerald....... 8
...m.......... 2	Fluor-spar.... 4	Quartz........ 7	Topaz......... 8
.... 2.5	Feldspar 6	Tourmalin 7	Ruby......... 9
...nate of lime. 3	Lapis Lazuli . 6	Garnet....... 7.5	Diamond..... 10

Weight of Diamonds.

	Carats.		Carats.		Carats.
...n............	367	Regent or Pitt.....	136.75	Dresden..........	76.5
...Mogul*.......	279.9	Star of the South†..	125	Sancy...........	53.5
....	194.25	Koh-i-Noor‡.......	106.06	Eugenie, brilliant .	51
...tine, brilliant .	139.5	Piggott	82.25	Hope (blue).......	48.5
...of Portugal...	138.5	Napac	78.625	Polar Star........	40.25

...ugh 900. † Rough 254.5. ‡ Originally 793.

Heat of the Sun.

...ac Newton............	3 138 740°	Waterston.................	16 000 000°
...ohn Ericsson...........	4 909 860°	Soret......................	10 443 323°

...ry others ranging from 2520° to 183 600°.

...—Distance of Moon from Earth 237 000 miles.

Frigorific Mixture.

...st temperature yet procured. Faraday obtained 166° by evaporation of a ...e of solid carbonic acid and sulphuric ether.

Current of Rivers.

...of .1 of an inch in a mile will produce a current in rivers.

Sandstones.

...tures of sandstone erected in England in 12th century are yet in good ...n.

Canal Transportation.

...Canal and Hudson River.—From Buffalo to New York, 495 miles, cost of ...rtation 2.46 mills per ton (inclusive of tolls) per mile. Transportation of ...osts when it reaches New York 4.72 cents per bushel, and .61 cents per ...or elevating and trimming.

...*—Erie Canal.*—Four mules will tow 22... freight down and 100 ... *involving a period of 30 days, at a cost* ... mile for a course

Matter.

Unit of the Physicist is a molecule, and a mass of matter is composed o having same physical properties as parent mass.

It exists in three forms, known as solid, liquid, and gaseous. Solids ha viduality of form, and they press downward alone. Liquids have not indivi of form, except in spherical form of a drop, and they press downward and si Gases are wholly deficient in form, expanding in all directions, and conse they press upward, downward, and sideward.

Liquids are compressible to a very moderate degree. Water has been through pores of silver, and it may be compressed by a pressure of one po square inch to the 3 300 000th part of its volume.

Gases may be liquefied by pressure or by reduction of their temperature.

Combustible matter (as coal) may be burned, a structure (as a house) destroyed as such, and the fluid (of an ink) may be evaporated, yet the m which coal and house were composed, although dissipated, exists, and th and coloring matter of the ink are yet in existence.

Spaces between the particles of a body are termed pores.

All matter is porous. Polished marble will absorb moisture, as evidence discoloration by presence of a colored fluid, as ink, etc.

Silica is the base of the mineral world, and *Carbon* of the organized.

Minuteness of Matter.

A piece of metal, stone, or earth, divided to a powder, a particle of it, l minute, is yet a piece of the original material from which it was separated ing its identity, and is termed a molecule.

It is estimated there are 120 000 000 corpuscles in a drop of blood of the mu

Thread of a spider's web is of a cable form, is but one sixth diameter of a silk, and 4 miles of it is estimated to have a weight of but 1 grain.

One imperial gallon (277.24 cube ins.) of water will be colored by mixture of a grain of carmine or indigo.

A grain of platinum can be drawn out the length of a mile.

Film of a soap-and-water bubble is estimated to be but the 300 000th pa inch in thickness.

It is computed that it would require 12 000 of the insect known as the monad to fill up a line one inch in length.

A drop of water, or a minute volume of gas, however much expanded— the volume of the Earth—would present distinct molecules.

Gold leaf is the 280 000th part of an inch in thickness.

A thread of silk is 2500th of an inch in diameter.

A cube inch of chalk in some places in vicinity of Paris contains 100 000 of the foraminifera.

There are animalcules so small that it requires 75 000 000 of them to weigh

Velocity, Weight, and Volume of Molecules.

Velocity.—Collisions among the particles of *Hydrogen* are estimated to the rate of 17 million-million-million per second, and in *Oxygen* less than number.

Weight.—A million-million-million-million molecules of *Hydrogen* are e to weigh but 60 grains.

Volume.—19 million-million-million molecules of *Hydrogen* have a volum cube ins. *Diameter.*—Five millions in a line would measure but .1 inch.

Charcoal, Alcohol.

Charcoal as yet has not been liquefied, nor has Alcohol been solidified.

Metals.

Metals have five degrees of lustre—*splendent*, *shining*, *glistening*, *glimmer*

...ls can be vaporized, or exist as a gas, by application to them of t ...ature of conversion.

...ring of a metal renders it brittle; reheating it restores its t ... renders it harder, and up to twelfth time it

of all metals.

Impenetrability.

penetrability expresses the inability of two or more bodies to occupy same at same time.

nixture of two or more fluids may compose a less volume than that due to sum eir original volume, in consequence of a denser or closer occupation of their cules. This is evident in the mixture of alcohol and water in the proportion 5 volumes of former to 25 of latter, when there is a loss of one volume.

Elasticity.

sticity is the term for the capacity of a body to recover its former volume, being subjected to compression by percussion or deflection.

ss, ivory, and steel are the most elastic of all bodies, and clay and putty are rations of bodies almost devoid of elasticity. Caoutchouc (India rubber) is but rately elastic; it possesses contractility, however, in a great degree.

Momentum.

mentum is quantity of motion, and is product of mass and its velocity. Thus, nomentum of a cannon-ball is product of its velocity in feet per second and its ht, and is denominated *foot-pounds*.

foot-pound is the power that will raise one pound one foot.

Sound.

locity of sound is proportionate to its volume; thus, report of a blast with 2000 of powder passed 967 feet in one second, and one of 1200 lbs. 1210 feet. It passes ater with a velocity of 4708 feet per second. Conversation in a low tone has maintained through cast-iron water pipes for a distance of 3120 feet, and its city is from 4 to 16 times greater in metals and wood than air.

Light.

n's rays have a velocity of 185000 miles per second, equal to 7.5 times around Earth.

Color Blindness

sence of elementary sensation corresponding to red.

Luminous Point.

produce a visual circle, a luminous point must have a velocity of 10 feet in a nd, the diameter not exceeding 15 ins.

l solid bodies become luminous at 800 degrees of heat.

Mirage.

hen air near to surface of Earth becomes so highly heated, as upon a sandy , that its density within a defined distance from it increases upwards, a line sion directed obliquely downwards will be rendered by refraction, gradually asing, more and more nearly horizontal as it advances, until its direction is so as to produce a total reflection, and the reflected ray then, by successive re- ions, is gradually elevated until it meets the eye of the observer.

oming is inverted mirage, frequently seen over calm water, and is effect of or surface stratum of air being colder than that above it.

Snow Flakes.

forms of snow flakes have been observed.

Melted Snow

duces from .25 to .125 of its bulk in water.

Strength of Ice.

inches thick will support men in single file on planks 6 feet apart; 4 inches upport cavalry, light guns, and carts; and 6 inches wagons drawn by horses.

Temperature.

phuric acid and water produce a much greater proportionate contraction than l and water. Both of these mixtures, however low their temperature, pro- heat which is in a direct proportion to their diminution in volume.

the depth of 45 feet, the temperature of the Earth is uniform throughout the

perature of Earth *increases about* 1° for every 50 to 60 feet.

is estimated at 30 miles.

dy at Equator weighs two hundred and eighty-nine parts less

Ages of Animals, Fishes, etc.

(Additional to page 192.)

Tiger, Leopard, Jaguar, and Hyena (in confinement), 25 years; Beaver, 50; Stag under 50; Ox and Ass, 30; Chamois, 25; Llama, Monkey, and Baboon, 15 to 18; Parrot, 200; Tortoise, 100 to 200; Crocodile, 100; Carp, 70 to 150; Goose, 80; Pelican, 45; Hawk, 30 to 40; Crane, 24; Peacock, Goldfinch, Chaffinch, from 10 to 25; Domestic Fowls, Pigeons, Blackbird, Nightingale, and Linnet, 10 to 16; Thrush, Robin, and Starling, 8 to 12; Wren, 2 to 3; Salmon, 16; Eel, 10; Codfish, 4 to 17; Pike, 30 to 40; Queen Bee, 4; Bee, 6 months, and Drones, 4 months. (*Houghtaling.*)

Birds and Insects.—(*M. De Lacy.*)

Elements of Flight.—Resistance of air to a body in motion is in ratio of surface of body and as square of its velocity.

Wing Surface.—Extent or area of winged surface is in an inverse ratio to weight of bird or insect.

A Stag-beetle weighs 460 times more than a Gnat, and has but one fourteenth of its wing surface; 150 times more than a Lady Bird (bug), and has but one fifth. An Australian Crane weighs 339 times more than a sparrow, and has but one seventh; 3 000 000 times more than a Gnat, and has but one hundred and fortieth. A Stork weighs eight times more than a Pigeon, and has but one half. A Pigeon weighs ten times more than a Sparrow, and has but one half; 97 000 times more than a Gnat, and has but one fortieth.

A resisting surface of 30 sq. yards will enable a man of ordinary weight to descend safely from a great elevation.

Strength of Insects.—Insects are relatively strongest of all animals. A Cricket can leap 80 times its length, and a Flea 200 times.

Application for Stings and Burns.

Sting of Insects.—Ammonia, or Soda moistened with water, and applied as a paste.

Burns.—Hot alcohol or turpentine, and afterwards bathed with lime water and sweet oil. Cold water not to be applied.

To Preserve Meat.

Meat of any kind may be preserved in a temperature of from 80° to 100°, for a period of ten days, after it has been soaked in a solution of 1 pint of salt dissolved in 4 gallons of cold water and .5 gallon of a solution of bisulphate of calcium.

By repeating this process, preservation may be extended by addition of a solution of gelatin or white of an egg to the salt and water.

To Detect Starch in Milk.

Add a few drops of acetic acid to a small quantity of milk; boil it, and after it has cooled filter the whey. If starch is present, a drop of iodine solution will produce a blue tint.

This process is so delicate that it will show the presence of a milligram of starch in a cube centimeter of whey (1 grain of starch in 2.16 fluid-ounces).

Retaining Walls of Iron Piles.

Sheet Piles.—7 feet from centres, 18 ins. in width and 2 ins. in thickness, strengthened with 2 *ribs* 8 ins. in depth.

Plates.—7 feet in length by 5 feet in width and 1 inch in thickness, with diagonal feather 1 by 6 ins.

Tie-rods 2 ins. in diameter.

Stone Sawing.

Diamond Stone Sawing.—(*Emerson.*) Alabama marble 6 feet × 2.5 feet in 22 min. = 41 sq. feet per hour.

Wood Sawing.

...oard measure, from 9 round logs in 1 hour. Engine 12 ... ce.

Cost of Dredging.

ll cost, if on an extended work, inclusive of Delivery, if dredging into or on a vessel alongside of dredger.—(*Trautwine.*)

Labor at $ 1 per day and Repairs of Plant included.

h.	Cents.	Depth.	Cents.	Depth.	Cents.	Depth.	Cents.
.	Cube Yards.	Feet.	Cube Yards.	Feet.	Cube Yards.	Feet.	Cube Yards.
	6	20	8	25	10	35	18
	7	22	9	30	13	40	25

charge of Scows or Camels.—Towing .25 mile 4 cents per cube yard, .5 mile 6 , .75 mile 8 cents, and 1 mile 10 cents.

re. —A *Scow* is a flat-bottomed vessel or boat. A *Camel* is a shallow, flatmed and decked vessel, designed for the transportation of heavy freight or the ining of attached bodies, as a vessel, by its buoyancy.

Dredging.

team dredge will raise 6 cube yards, or 8.5 tons, per hour per IP.

Metal Boring and Turning.

RING.—*Cast iron.*—Divide 25 by the diameter of the cylinder in inches for the ations per minute.

rought iron.—The speed is one fourth to one fifth greater than for cast iron.

ass.—The speed is about twice that for cast iron.

RNING.—*Cast iron.*—The speed is twice that of boring.

rought iron.—The speed is one fourth to one fifth greater than that for cast iron.

ass.—The speed is twice that of boring.

rtical boring.—The speed may be twice that of horizontal boring.

e *feed* depends upon the stability of the machine and depth of the cut.

Well Boring.

Coventry, Eng., 750 000 galls. of water per day are obtained by two borings of 18 ins., at depths of 200 and 300 feet.

Liverpool, Eng., 3 000 000 galls. of water per day are obtained by a bore 6 ins. ameter and 161 feet in depth.

is large yield is ascribed to the existence of a *fault* near to it, and extending to th of 484 feet.

Kentish Town, Eng., a well is bored to the depth of 1302 feet.

Passy, France, a well with a bore of 1 meter in diameter is sunk to a depth of feet, and for a diameter of 2 feet 4 ins. it is further sunk to a depth of 109 feet ., or 1903 feet 10 ins., from which a yield of 5 582 000 galls. of water are obtained ay.

Tempering Boring Instruments.

it the tool to a blood-red heat; hammer it until it is nearly cold; reheat it to d-red heat, and plunge it into a mixture of 2 oz. each of vitriol, soda, sal-amic, and spirits of nitre, 1 oz. of oil of vitriol, .5 oz. of saltpetre, and 3 galls. of , retaining it there until it is cool.

Circular Saws.

olutions per Minute.—8 ins. 4500, 10 ins. 3600, and 36 ins. 1000.

Masonry.

crete or Beton should be thrown, or let fall from a height of at least 10 feet, l beaten down.

average weight of brickwork in mortar is about 102 lbs. per cube foot.

Plastering.

measuring Plasterers' work all openings, as doors, windo[illegible] com. at one half of their areas, and cornices are measured u[illegible] including that cut off by mitring.

Glazing.

laziers' work, oval and round windows are measured as sq[illegible]

r. S. ENSIGN, PENNANTS, AND FLAGS.

(*From July* 4, 1890.)

——*Head* (*Depth*, or *Hoist*).—Ten nineteenths of its length.

·rteen horizontal stripes of equal breadth, alternately red and ·ng with red.

blue field in upper quarter, next the head, .4 of length of field, pes in depth, with white stars ranged in equidistant, horizontal staggered, equal in number to number of States of the Union.

:s (Narrow).—*Head.*—6.24 ins. to a length of 70 feet; 5.04 ins. to a et; 4.2 ins. to a length of 35 feet. *Night*, 3.6 ins. to a length of 20 · to a length of 9 feet.—*Boat*, 2.52 ins. to a length of 6 feet.

lue field at head, one fourth the length, with 13 white stars in a hori- *Field.*—A red and white stripe uniformly tapered to a point, red up- *ght and Boat Pennants.*—Union to have but 7 stars.

Jack.—Alike to the Union of an Ensign in dimensions and stars.

–President.—Rectangle, with arms of the U. S. in centre of over which are 13 stars in an arc.

ry of Navy.—Rectangle, with a vertical white foul anchor a blue field, with four white stars in a rectangle, set quadrilateral ul anchor.

al.—Rectangle, with 4 white stars in centre of a blue field, set as

.dmiral.—Same as Admiral's, with 3 white stars set as an triangle.

dmiral.—Same as Admiral's, with 2 white stars set vertically. nore Rear-Admirals in command afloat should meet, their seniority is ted respectively by a Blue flag, a Red with White stars, and a White rs, and another or all others, a White flag with Blue stars.

odore. (*Broad Pennant.*)—Blue, Red, or White, according to ne star in centre of field, being white in blue and red pennants, white.

iled, angle at tail, bisected by a line drawn at a right angle from centre oist, and at a distance from head of three fifths of length of pennant; e rectangular with head or hoist; upper side tapered, running the width t the tails .1 the hoist. *Head.*—6 *length.* *Fly* 1.66 *hoist.*

nal Marks.—Triangle, 1st Blue, 2d Red, 3d White, Blue *Reserve Division.*—Yellow, Red vertical. Division mark is worn nder of a division of a squadron at mizzen, when not authorized ad Pennant of a Commodore or Flag of an Admiral. *Fly* .8 *hoist.*

Numbers.—*Fly* 1.25 *hoist.* *Signal Pennants, Fly* 4.6 *hoist.* .89 *hoist.*

ctive Pennants.—Of a Senior Officer Present, is the Dis- rk of the First Division of a fleet.

Signals.—Very's System.

nal, Signal Number, Square, and Signal Pennants. *Fly* .3 *hoist.*

Suspension Bridges. *Length of Spans in Feet.*

lina	330	Niagara	822
'hila.)	342	Lewistown and Queenstown	1040
th, Eng.	422	Cincinnati	1057
e)	660	Niagara Fall	1280

and Brooklyn, 930, 1595.5, and 930; clea ·ʌg *135 feet.*

Alimentary Principles.

Primary division of Food is into Organic and Inorganic.

Organic is subdivided into Nitrogenous and Non-Nitrogenous; Inorganic is composed of water and various saline principles. The former elements are destined for growth and maintenance of the body, and are termed "plastic elements of nutrition." The latter are designed for undergoing oxidation, and thus become source of heat, and are termed "elements of respiration," or "Calorificient."

Although Fat is non-nitrogenous, it is so mixed with nitrogenous matter that it becomes a nutrient as well as a calorificient.

Alimentary Principles. — 1. Water; 2. Sugar; 3. Gum; 4. Starch; 5. Pectine; 6. Acetic Acid; 7. Alcohol; 8. Oil or Fat. *Vegetable and Animal.*—9. Albumen; 10. Fibrine; 11. Caseine; 12. Gluten; 13. Gelatine; 14. Chloride of Sodium.

These alimentary principles, by their mixture or union, form our ordinary food, which, by way of distinction, may be denominated *compound aliments;* thus, meat is composed of fibrine, albumen, gelatine, fat, etc.; wheat consists of starch, gluten, sugar, gum, etc.

Analysis of Meats, Fish, Vegetables, etc.

Food.	Water.	Nitrogenous Matter.	Fat.	Saline Matter.	Non-Nitrogenous Matter.	Sugar.	Cellulose.	Ash, etc.
Arrowroot	18	—	—	—	82	—	—	—
Barley Meal	15	6.3	2.4	2	69.4	4.9	—	—
Beans, White	9.9	25.5	2.8	—	55.7	—	2.9	3.2
Beef, roast	54	27.6	15.45	2.95	—	—	—	—
fat	51	14.8	29.8	4.4	—	—	—	—
lean	72	19.3	3.6	5.1	—	—	—	—
salt	49.1	29.6	.2	21.1	—	—	—	—
Beer and Porter	91	.1	—	.2	8.7	—	—	—
Buckwheat	13	13.1	3	.4	64.5	—	3.5	2.5
Butter and Fats	15	—	83	2	—	—	—	—
Cabbage	91	2	.5	.7	5.8	—	—	—
Carrots	83	1.3	.2	1	7.4	6.1	—	1
Cheese	36.8	33.5	24.3	5.4	—	—	—	—
Corn Meal	14	11.1	8.1	1.7	57.6	.4	5.9	1.3
Cream	66	2.7	26.7	1.8	—	2.8	—	—
Egg	74	14	10.5	1.5	—	—	—	—
yolk	52	16	30.7	1.3	—	—	—	—
Fish, white flesh	78	18.1	2.9	1	—	—	—	—
Eels	75	9.9	13.8	1.3	—	—	—	—
Lobster, flesh	76.6	19.17	1.17	1.8	1.26	—	—	—
Oysters	80.39	14.01	1.52	2.7	1.38	—	—	—
Liver, Calf's	72.33	20.55	5.58	1.54	—	—	—	—
Milk, Cow's	86	4.1	3.9	.8	—	5.2	—	—
Mutton, fat	53	12.4	31.1	3.5	—	—	—	—
Oatmeal	15	12.6	5.6	3	58.4	5.4	—	—
Oats	21	14.4	5.5	—	48.2	—	7.6	3.3
Parsnips	82	1.1	.5	1	9.6	5.8	—	—
Peas	15	23	2.1	2.5	50.2	2	3.1	2.1
Pork, fat	39	9.8	48.9	2.3	—	—	—	—
Bacon, dry	15	8.8	73.3	2.9	—	—	—	—
Potatoes	75	2.1	.2	.7	16.8	3.2	1	1
Poultry	74	21	3.8	1.2	—	—	—	—
Rice	13	6.3	.7	.5	78.1	.4	—	1
Rye Meal	15	8	2	1.8	69.5	3.7	—	—
Sugar	5	—	—	—	95	—	—	—
Tripe	68	13.2	16.4	2.4	—	—	—	—
Turnips	91	1.2	—	.6	4.3	2.1	—	.8
Veal	63	16.5	15.8	4.7	—	—	—	—
Wheat Flour	15	10.8	2	1.7	61.1	4.2	3.5	1.7
Bread *	37	8.1	1.6	2.3	45.4	3.6	—	2
Bran		18	6	—	60	—	—	1

* *Water absor*[illegible] ...om 40 to 60 per cent. of weight of flour, the best quality [illegible] *ing most.* 100 [illegible] ...bread.

Analysis of Different Foods
In their Natural Condition.

	Nitrates.	Carbonates.	Phosphates.	Water.		Nitrates.	Carbonates.	Phosphates.	Water.
…s..........	5	10	1	84	Milk of cow..	5	8	1	86
…y..........	17	69.5	3.5	10	Mutton......	12.5	40	4.5	43
…s..........	24	57.7	3.5	14.8	Oats..........	17	66.4	3	13.6
....	15	30	5	50	Parsnips.....	9.2	7	1	82.8
…wheat ..	8.6	75.4	1.8	14.2	Pork..........	10	50	1.5	38.5
…age	4	5	1	90	Potatoes	2.4	22.5	.9	74.2
…en	19	3.5	4.5	73	" sweet	1.5	28.4	2.6	67.5
…North'n	12	73	1	14	Rice..........	6.5	79.5	.5	13.5
…South'n	35	48	3	14	Turnips......	5	4	.5	90.5
…mbers...	1.5	1	.5	97	Veal..........	16	16.5	4.5	63
…........	11	35.5	3.5	50	Wheat.......	15	69.2	1.6	14.2

…trates—Are that class which supplies waste of muscle.

…rbonates—Are that class which supplies lungs with fuel, and thus furnishes heat …e system, and supplies fat or adipose substances.

…osphates—Are that class which supplies bones, brains, and nerves, and gives power, both muscular and mental.

…om above it appears, that Southern corn produces most muscle and least fat, …contains enough of phosphates to give vital power to brain, and make bones …g. Mutton is the meat which should be eaten with Southern corn.

…e nitrates in all the fine bread which a man can eat will not sustain life beyond …days; but others, fed on unbolted flour bread, would continue to thrive for an …finite period. It is immaterial whether the general quantity of food be reduced …ow, or whether either of the muscle-making or heat-producing principles be …drawn while the other is fully supplied. In either case the effect will be the …. A man will become weak, dwindle away and die, sooner or later, according to …deficiency; and if food is eaten which is deficient in either principle, the appe…will demand it in quantity till the deficient element is supplied. All food, be… the amount necessary to supply the principle that is not deficient, is not only …ed, but burdens the system with efforts to dispose of it.

Analysis of Fruits.

Fruit.	Water.	Sugar.	Acid.	Albuminous substances.	Insoluble matter.	Pectous substances.	Ash.
…, white..........	85	7.6	1	.22	1.83	3.88	.47
…ot, average.......	83.5	1.8	1.1	.51	4.7	7.55	.84
…berry	86.4	4.44	1.19	.51	5.26	1.72	.48
…y, red...........	75.4	13.1	.35	.9	5.83	3.73	.69
sour..........	80.5	8.77	1.28	.83	5.91	2.07	.64
black	79.7	10.7	.56	1	6.04	1.33	.67
…it, red...........	85.4	5.6	1.7	.36	3.74	2.4	.8
…berry, red.......	85.6	8	1.35	.44	2.92	1.26	.43
yellow....	85.4	7	1.2	.46	3.17	2.4	.37
white..........	80	13.78	1	.83	2.48	1.44	.47
Dutch..........	85	1.58	.61	.46	5.49	6.4	.46
…ed	83.5	7.5	.07	.25	3.54	4.8	.34
yellow gage....	80.8	2.96	.96	.48	3.98	10.48	.34
large "	79.7	3.4	.87	.4	3.91	11.3	.42
black blue.....	88.7	2	1.27	.4	6.86	.23	.54
" red......	85.3	2.25	1.33	.43	4.23	5.85	.61
Italian. sweet...	81.3	6.73	.84	.83	4.01	5.63	.66
…rry, wild.......	83.9	3.6	2	.55	8.37	1.28	.4
…erry, "	87	4	1.5	.6	5.5	.4	1
….............	73.9	Sugar, Pectin, Salt, Acid, etc., 26.1.					

…r and Water in Various Products not Included in the Table. (*Per Cent.*)

	Sugar.		Water.		
…crude	95	*Molasses*.............	23	Cabbage...	
…s............	77	*Lean beef*.............	72	Ale and Be…	
…milk.........	6.4	*Buttermilk*...........	88	Coffee and…	

Relative Values of Foods or Assimilating Quality to make an Equal Quantity of Flesh in Cattle or Sheep.

(*Ewart.*)

Article.	Cattle.	Sheep.	Article.	Cattle.	Sheep.
Turnips	800	400	Wheat bran	45	105
Carrots	630	—	Corn and Barley meal	35	—
Beets	600	300	Oatmeal	34	—
Parsnips and Swedes	600	200	Beanmeal	33	—
Meadow grass in bloom	400	—	Peameal	32	—
Vetches, pods open	360	90	Cabbage	—	500
Potatoes at maturity	280	200	Pea straw	—	200
Oat straw, cut green	125	—	Rye bran	—	109
Bean or Vetch straw	—	200	Oats	—	70
Meadow hay	100	100	Buckwheat	—	65
Vetch "	90	—	Barley	—	60
Linseed cake	50	—	Pease or Beans	—	54

NOTE.—When these values express weight in lbs., then such food will produce about 4 to 5 lbs. beef or mutton.

Nutritive Constituents and Values of Food in Grains per Pound.

Food.	Carbon.	Nitrogen.	Food.	Carbon.	Nitrogen.
Bakers' Bread	1975	88	Mutton	1900	189
Barley Meal	2563	68	New Milk	599	44
Beef	1854	184	Oatmeal	2831	136
Beer and Porter	274	1	Parsnips	554	12
Bullock's Liver	934	204	Pearl Barley	2660	91
Buttermilk	387	44	Potatoes	769	22
Carrots	508	14	Red Herrings	1435	217
Cheddar Cheese	3344	306	Rice	2732	68
Cocoa	3934	140	Rye Meal	2693	86
Dry Bacon	5987	95	Salt Butter	4585	—
Fat Pork	4113	106	Skim Cheese	1947	483
Flour, Seconds	2700	116	Skimmed Milk	438	43
Fresh Butter	6456	—	Split Pease	2698	248
Green Bacon	5426	76	Suet	4710	—
Green Vegetables	420	14	Sugar	2955	—
Indian Meal	3016	120	Turnips	263	13
Lard	4819	—	Whey	154	13
Molasses	2395	—	Whitefish	871	195

The *Full Daily Diet* of a man is held to be 12 oz. bread, 8 oz. potatoes, 6 oz. meat, 4 oz. boiled rice with milk, .375 pint of broth or pea soup, 1 pint milk, and 1 pint of beer.

Nutritive Values and Constituents of Milk.—(*Payen.*)

Animal.	Nitrogenous Matter and insoluble Salts.	Butter.	Lactic and soluble Salts.	Water.	Animal.	Nitrogenous Matter and insoluble Salts.	Butter.	Lactic and soluble Salts.	Water.
Goat	4.5	4.1	5.8	85.6	Ass	1.7	1.4	6.4	90.5
Cow	4.55	3.7	5.35	86.4	Mare	1.62	.2	8.75	89.43
Woman	3.35	3.34	3.77	89.54	Ewe	4.68	4.2	5.5	85.6[illegible]

Weight of some Different Foods required to furnish 1220 Grains of Nitrogenous Matter.

	Lbs.		Lbs.		Lbs.		Lbs.
Cheese	.4	Meat, fat	1.3	Bacon, fat	1.8	Barley Meal	[illegible]
Pease	.7	Oatmeal	1.5	Bread	2.1	Milk	[illegible]
Meat, lean	.9	Corn Meal	1.6	Rye Meal	2.3	Potatoes	[illegible]
Fish, White	1	Wheat Flour	1.7	Rice	2.8	Parsnips	[illegible]

Turnips, 15.9 lbs.; Beer or Porter, 158.6 lbs.

Proportion of Sugar and Acid in Various Fruits.

(*Fresenius.*)

FRUIT.	Sugar.	Acid.	FRUIT.	Sugar.	Acid.
	Per Cent.	Per Cent.		Per Cent.	Per Cent.
le..............	8.4	.8	Plum...............	2.1	1.3
icot............	1.8	1.1	Prune..............	6.3	.9
kberry.........	4.4	1.2	Raspberry..........	4	1.5
rants...........	6.1	2	Red Pear...........	7.5	.1
seberry.........	7.2	1.5	Sour Cherry........	8.8	1.3
pe..............	14.9	.7	Strawberry.........	5.7	1.3
berry.....	9.2	1.9	Sweet Cherry.......	10.8	.6
ch..............	1.6	.7	Whortleberry.......	5.8	1.3

roportion of Oil in Various Air-dry Seeds. (*Berjot.*)

chnut......	24	Mustard.......	30	Almond.......	40	Orange........	40
np.........	28	Flax..........	34	Colza.........	40 / 45	Poppy........	40 / 50
ermelon ...	36	Peanut........	38				

nalysis of different Articles of Food, with Reference nly to their Properties for giving Heat and Strength.

(*Payen.*) *In* 100 *Parts.*

BSTANCES.	Carbon.	Nitrogen.	SUBSTANCES.	Carbon.	Nitrogen.	SUBSTANCES.	Carbon.	Nitrogen.
hol.......	52	—	Coffee........	9	1.1	Oil, Olive.....	98	—
ley........	40	1 9	Corn..........	44	1.7	Oysters	7.18	2.13
ns.........	42	4.5	Eels..........	30.05	2	Pease.........	44	3.66
, meat....	11	3	Eggs..........	13.5	1.9	Potatoes......	11	.33
, strong..	4.5	.08	Figs, dried....	34	.92	Rice..........	41	1.8
d, stale...	28	1.07	Herring, salted..........	23	3.11	Rye Flour....	41	1.75
kwheat...	42.5	2.2				Salmon	16	2.09
er.......	83	.64	Liver, Calf's..	15.68	3.93	Sardines......	29	6
ots.......	5.5	.31	Lobster	10.06	2.93	Tea...........	2.1	.2
are	27.41	4.49	Mackerel.....	19.26	3.74	Truffes.......	9.45	1.35
se, Chest'r	41.04	4.13	Milk, Cow's...	8	.66	Wheat........	41	3
olate	58	1.52	Nuts.........	10.65	1.4	" Flour..	38.5	1.64
fish, salt'd	16	5.02	Oatmeal......	44	1.95	Wine	4	.015

TE.—Multiply figures representing nitrogen by 6.5, and equivalent amount of genous matter is obtained.

Human and Animal Sustenance.

Least Quantity of Food required to Sustain Life. (*E. Smith, M.D.*)

	Carbon. Grs.		Hydrogen. Grs.	
Adult Man.	4300	Mean, 4100.	200	Mean, 190.
Adult Woman,	3900		180	

adult man, for his daily sustenance, requires about 1220 grs. nitrog-s matter or 200 of nitrogen, and bread contains 8.1 per cent. of it.

nce, $\frac{1220}{.081}$ = 15062 *grains which* ÷ 7000 *in a lb.* = 2 *lbs.* 2.43 *oz.* of bread.

ese quantities and proportions are also contained in about 16 lbs. of ps.

s, by table of nutritive values, page 202, turnips have 263 grains of carbon and nitrogen.

nce, $\frac{4300}{263}$ and $\frac{200}{13}$ = 16.35 *lbs. for the necessary carbon and* 15.4 *lbs. for the* *en.*

lative Value of Foods compared with 100 [illegible] Good Hay.

	Lbs.		Lbs.		Lbs.	
r, green..	400	*Rye straw.....*	*442*	Carrots.......	276	Corn..
green ...	*275*	*Oat straw.....*	*195*	Barley........	54	Linsee
straw..	*374*	*Cornstalks....*	*400*	Oats..........	57	Whea.

Weight of Articles of Food required to be consumed in the human system to develop a power equal to raising 140 lbs. to a height of 10 000 feet. (*Frankland.*)

SUBSTANCES.	Weight.	SUBSTANCES.	Weight.	SUBSTANCES.	Weight.
	Lbs.		Lbs.		Lbs.
Cod-liver oil.......	.553	Rice.............	1.341	Salt Beef	3.65
Beef, fat..........	.555	Isinglass...........	1.379	Veal, lean.........	4.3
Bacon..............	.67	Sugar, lump	1.505	Porter............	4.65
Butter............	.693	Cream............	2.062	Potatoes..........	5.068
Cocoa	.797	Egg, boiled........	2.209	Fish..............	6.369
Fat of Pork.......	.97	Bread	2.345	Apples............	7.815
Cheese...........	1.156	Salt Pork.........	2.826	Milk..............	8.021
Oatmeal..........	1.281	Ham, lean, boiled..	3.001	Egg, white of......	8.745
Arrowroot.........	1.287	Mackerel	3.124	Carrots...........	9.685
Wheat flour.......	1.311	Ale, bottled.......	3.461	Cabbage..........	12.02

Relative Value of Various Foods as Productive of Force when Oxidized in the Body.

Cabbage.......	1	Porter	2.6	Egg, hard boil'd	5.4	Oatmeal.....	9.3
Carrots........	1.2	Veal, lean.....	2.8	Cream	5.9	Cheese......	10.4
Skimmed Milk.	1.2	Salt Beef......	3.3	Egg, yolk......	7.9	Fat of Pork.	12.4
White of Egg..	1.4	Poultry	3.3	Sugar..........	8	Cocoa.......	16.3
Milk...........	1.5	Lean Beef.....	3.4	Isinglass......	8.7	Pemmican..	16.9
Apples........	1.5	Mackerel......	3.8	Rice...........	8.9	Butter......	17.3
Ale............	1.8	Ham, lean.....	4	Pea Meal......	9.	Bacon.......	17.46
Fish...........	1.9	Salt Pork......	4.3	Wheat Flour ..	9.1	Fat of Beef..	21.6
Potatoes	2.4	Bread, crumb..	5.1	Arrowroot.....	9.3	Cod-liver Oil.	21.7

Nutritious Properties of different Vegetables and Oil-cake, compared with each other in Quantities.

Oil-cake.......	1	Rye.........	2.5	Clover hay.....	4	Cabbage......	18
Pease and Beans	1.5	Bran, wheat	2.75	Hay...........	5	Wheat straw..	26
Wheat, flour...	2		3	Potatoes.......	14	Barley "	26
" grain ..	2.5	Corn........	3	" old....	20	Oat "	27.5
Oats..........	2.5	Barley......	3	Carrots	17.5	Turnips......	30

ILLUSTRATION.—1 lb. of oil-cake is equal to 18 lbs. of cabbage.

Volume of Oxygen required to Oxidize 100 parts of following Foods as consumed in the Body.

Grape Sugar .. 106 | Starch........ 120 | Albumen...... 150 | Fat........... 293

Hence, assuming capacity for oxidation as a measure, albumen has half value of fat as a food-producing element, and a greater value than either starch or sugar.

Proportion of Alcohol in 100 Parts of following Liquors. (*Brande.*)

Small Beer...	1 and 1.08	Hermitage, red	12.32	Lisbon	18.94
Porter.......	3.5 and 5.26	Champagne.........	12.61	Lachryma..........	19.7
Cider........	5.2 and 9.8	Amontillado........	12.63	Teneriffe	19.79
Brown Stout.	5.5 and 6.8	Frontignac.........	12.89	Currant Wine.......	20.55
Ale.........	6.87 and 10	Barsac.............	13.86	Madeira............	22.27
Rhenish...........	7.58	Sauterne...........	14.22	Port	23
Moselle	8.7	Champagne Burg'dy,	14.57	Sherry, old	23.86
Johannisberger.....	8.71	White Port.........	15	Marsala	25.09
Elder Wine.........	8.79	Bordeaux	15.1	Raisin Wine........	25.12
Claret ordinaire.....	8.99	Malmsey...........	16.4	Madeira, Sercial	27.4
Tokay.............	9.33	Sherry.............	17.17	Cape Madeira.......	29.51
Rudesheimer.......	10.72	Malaga.............	17.2	Gin................	51.6
Marcobrunner......	11.6	Alba Flora.........	17.26	Brandy	53.39
Gooseberry Wine ...	11.84	Hermitage, white ...	17.43	Rum...............	53.68
Hockheimer........	12.03	Cape Muscat........	18.25	Irish Whiskey	53.9
Vin de Grave.......	12.08	Constantia, red	18.92	Scotch Whiskey	54.32

oportion of Food Appropriated and Expended by following Animals.

	Oxen.	Sheep.	Swine.
Proportion appropriated	6.2	8	17.6
" in manure	36.5	31.9	16.9
" respired	57.3	60.1	65.5
	100	100	100

ecific Gravity of Milk and Percentage of Cream, etc.

Milk.	Specific Gravity.	Volume of Cream.	Volume of Curd.	Specific Gravity when skimmed.
k, pure*	1030	12	6.3	1032
10 per cent. water	1027	10.5	5.6	1029
20 " " "	1024	8.5	4.9	1026
30 " " "	1021	6	4.2	1023

* For a method of testing the purity of milk, see Pavy on Food (Philadelphia, 1874), page 196.

OTE.—The average proportion of cream is 10, or 10 *per cent.*

oportion Per cent. of Starch in sundry Vegetables.

wroot	82	Wheat flour	66.3	Oatmeal	58.4	Potatoes	18.8
	79.1	Corn meal	64.7	Pease	55.4	Turnips	5.1

mposition of Cheese of Different Countries.—(*Payen.*)

	Fat.	Nitrogen.	Salt.	Water.		Fat.	Nitrogen.	Salt.	Water.
chatel..	18.74	2.28	4.25	61.87	Chester	25.41	5.56	4.78	30.39
esan...	21.68	5.48	7.09	30.31	Gruyères	28.4	5.4	4.29	32.05
	24.83	2.39	5.63	53.99	Marolles	28.73	3.73	5.93	40.07
nd	25.06	4.1	6.21	41.41	Roquefort	32.31	5.07	4.45	26.53

tritive Equivalents. Computed from Amount of Ni- ogen in Substances when Dried. Human Milk at 1.

	.81	Bread, White	1.42	Cheese	3.31	Lamb	8.33
oes	.84	Milk, Cows'	2.37	Eel	4.34	Egg, White	8.45
	1	Pease	2.39	Mussel	5.28	Lobster	8.59
	1.06	Lentils	2.76	Liver, Ox	5.7	Veal	8.73
t	1.19	Egg, Yolk	3.05	Pigeon	7.56	Beef	8.8
y	1.25	Oysters	3.05	Mutton	7.73	Pork	8.93
	1.38	Beans	3.2	Salmon	7.76	Ham	9.1

Herring, 9.14.

rmometric Power and Mechanical Energy of 10 rains of Various Substances in their Natural Con- tion, when Oxidized in the Animal Body into Car- onic Acid, Water, and Urea.—(*Frankland.*)

;ANCE.	Water raised 1°.	Lifted 1 foot high.	Substance.	Water raised 1°.	Lifted 1 foot high.	Substance.	Water raised 1°.	Lifted 1 foot high.
	Lbs.	Lbs.		Lbs.	Lbs.		Lbs.	Lbs.
ass's ..	1.99	1.54	Cheese	11.2	8.65	Mackerel	4.14	3.2
	1.48	1.29	Cocoa-nibs	17	7.3	Milk	1.64	1.25
root	10.06	7.77	Cod-liver oil	11	18.12	Oatme		7.8
ean	3.66	2.83	Egg, h'd boil.	5.86	4.53	Pea m		49
	5.52	4.26	" yolk	8.5	6.56	Potat		
	18.68	14.42	" white	1.48	1.14	Porte		
e	*1.08*	*.83*	*Flour, wheat.*	9.87	7.62	Rice,		
	1.33	*1.03*	*Ham, boiled.*	4.3	3.32	Suga		

S

Digestion.

Time required for Digestion of several Articles of Food.

(*Beaumont, M.D.*)

Food.	Time.	Food.	Time.
	h. m.		h. m.
Apple, sweet and mellow	1 50	Heart, Animal, fried	4
sour and mellow	2	Lamb, boiled	2 30
sour and hard	2 50	Liver, Beef's, boiled	2
Barley, boiled	2	Meat and Vegetables, hashed	2 30
Bean, boiled	2 30	Milk, boiled or fresh	2 2 15
Bean and Green Corn, boiled	3 45		
Beef, roasted rare	3	Mutton, roasted	3 15
roasted dry	3 30	broiled or boiled	3
Steak, broiled	3	Oyster	2 55
boiled	2 45	roasted	3 15
boiled, with mustard, etc.	3 30	stewed	3 30
Tendon, boiled	5 30	Parsnip, boiled	2 30
" fried	4	Pig, sucking, roasted	2 30
old salted, boiled	4 15	Feet, soured, boiled	1
Beet, boiled	3 45	Pork, fat and lean, roasted	5 15
Bread, Corn, baked	3 15	recently salted, boiled	4 30
Wheat, baked, fresh	3 30	" " fried	4 15
Butter, melted	3 30	" " broiled	3 15
Cabbage, crude	2 30	" " raw	3
crude, vinegar	2	Potato, boiled	3 30
crude, vin'r, boiled	4 4 30	baked roasted	3 [illegible] 2 30
Carrot, boiled	3 15	Rice, boiled	1
Cartilage, boiled	4 15	Sago, boiled	1 45
Cheese, old and strong	3 30	Sausage, Pork, broiled	3 20
Chicken, fricasseed	2 45	Soup, Barley	1 30
Custard, baked	2 45	Beef and Vegetables	4
Duck, roasted	4 4 30	Chicken Mutton or Oyster	3 3 30
Dumpling, Apple, boiled	3	Sponge-cake, baked	2 30
Egg	2	Suet, Beef, boiled	5 30
whipped	1 30	Mutton, boiled	4 30
boiled hard	3 30	Tapioca, boiled	2
" soft	3	Tripe, soured	1
fried	3 30	Turkey, roasted Wild	2 18
Fish, Cod or Flounder, fried	3 30	Turkey, roasted Domestic	2 30
Cod, cured, boiled	2	boiled	2 25
Salmon, salt'd and boil'd	4	Turnip, boiled	3 30
Trout, boiled or fried	1 30	Veal, roasted	4
Fowl, boiled or roasted	4	fried	4 30
Goose, roasted	3	Brain, boiled	1 45
Gelatine, boiled	2 30	Venison Steak, broiled	1 35

General Notes.

The per-centage of loss in the cooking of meats is as follows: Boiling 23; Baking 31; Roasting 34.

Potatoes possess anti-scorbutic power in a greater degree than any other of the succulent vegetables.

The average yearly consumption of wheat and wheat flour in Great Britain is [illegible] bushels per capita of its population.

The daily ration of an Esquimaux is 20 lbs. of flesh and blubber.—(Sir John [illegible]

n adult healthy man, according to Dr. Edward Smith, requires daily of

Phosphoric acid from ..	32 to 79 grains.	Potash	27 to 107 grains.
Chlorine............	51 " 175 "	Soda	80 " 171 "
Or of common salt...	85 " 291 "	Lime......	2.3 " 6.3 "

and of Magnesia 2.5 to 3 grains.

. common fowl's egg contains 120 grains of Carbon and 17.75 of Nitrogen.

.n ordinary working-man requires for his daily sustenance

Oxygen	1.47	Starch	.66
Albuminous matter.........	.305	Salts........................	.04
Fat	.22	Water........................	4.535

= 7.23 lbs. avoirdupois.

ilk.—If the milk of an animal is taken at three immediately successive periods, t which is first received will not be as rich in milk-fat as the last.
n a Devon cow, milked in this manner, the first milk gave but 1.166 per cent. of and the last, or that known as "strippings," 5.81 per cent.

Relative Richness of Milk of Several Animals.

Human Milk = 1.

	Milk-fat.	Casein.	Sugar.		Milk-fat.	Casein.	Sugar.
v.........	1.66	1.38	.69	Ass............	.5	.38	.94
re.........	1.19	.75	.94	Sheep..........	2.52	2.1	.72
it.........	2	1.04	.69	Camel..........	1.4	—	.96

he condensation of milk reduces it to about one third of its original volume.

. Farm of second-rate quality, properly cultivated, will sustain 100 head of cattle 100 acres, besides laboring-stock (employed in cultivation of farm), and swine. *Ewart.*)
hus, calves 25; do. 1 year 25; do. 2 years 25; cows 25.

ane Sugar (Saccharose)—Is insoluble in absolute alcohol, and in diluted alcohol soluble only in proportion to its weakness. Loaf sugar, as a rule, is chemically e.

eet Root Sugar—Contains 85 to 96 per cent. of cane sugar, 1.6 to 5.1 of organic ter, and 2 to 4.3 of water.

oney—Contains 32 per cent. of sugar (levulose), 25.5 of water, 27.9 of dextrine, 14.6 of other matter, as mannite, wax, pollen, and insoluble matter.

olasses—Contains 47 per cent. of cane sugar, 20.4 of fruit sugar, 2.6 of salts, 2.7 active and coloring matter, and 27.3 of water.

lour.—Tests of flour, see A. W. Blyth, London, 1882, page 152.

read.—Wheat, water lost by drying after 1 day 7.71 per cent., 3 days 8.86, and ys 14.05 per cent.

go.—2.5 lbs. per day will support a healthy man.

g—Contains nearly as much gluten as wheat bread (as 6 to 7), and in starch and r it is 16 per cent. richer.

oseberry (dry)—Is as nutritious as wheat bread.

atermelon, *Vegetable marrow*, and *Cucumber*—Contain 94, 95, and 97 per cent. ater respectively.

ion (dry)—Contains 25 to 30 per cent. of gluten. Potato containing but 5.

bbage, *Cauliflower*, *Broccoli*, and *Leaves* are generally rich in gluten, while the o is poor.

Ratio of Flesh-formers of Tubers.

Per Cent.

UBERS.	Flesh-formers.	Starch, etc.	Ratio to Heat-giv'rs.	TUBERS.	Flesh-formers.	Starch, etc.	Ratio to Heat-giv'rs.
root.....	.4	13.4	1:30	Parsnip......	1.2	8.7	
ip........	.5	4	1:8	Onion........	1.5	4.8	
t........	.5	5	1:10	Sweet Potato.	1.5	20.	
o........	1.2	18	1:16	Yam..........	2.2	16.	

GRAVITY OF BODIES.

Gravity acts equally on all bodies at equal distances from Earth's centre; its force diminishes as distance increases, and increases as distance diminishes.

Gravitating forces of bodies are to each other,

1. Directly as their masses.
2. Inversely as squares of their distances.

Gravity of a body, or its weight above Earth's surface, decreases as square of its distance from Earth's centre in semi-diameters of Earth.

Illustration 1.—If a body weighs 900 lbs. at surface of the Earth, what will it weigh 2000 miles above surface?—Earth's semi-diameter is 3963 miles (say 4000).

Then $2000 + 4000 = 6000 = 1.5$ *semi-diam's*, and $900 \div 1.5^2 = \frac{900}{2.25} = 400$ *lbs.*

Inversely, If a body weighs 400 lbs. at 2000 miles above Earth's surface, what will it weigh at surface?

$$400 \times 1.5^2 = 900 \text{ lbs.}$$

2.—A body at Earth's surface weighs 360 lbs.; how high must it be elevated to weigh 40 lbs.?

$\frac{360}{40} = 9$ *semi-diameters*, if gravity acted directly; but as it is inversely as square of the distance, then $\sqrt{9} = 3$ *semi-diameters* $= 3 \times 4000 = 12\,000$ *miles.*

3.—To what height must a body be raised to lose half its weight?

As $\sqrt{1} : \sqrt{2} :: 4000 : 5656$ = *as square root of one semi-diameter is to square root of two semi-diameters, so is one semi-diameter to distance required.*

Hence $5656 - 4000 = 1656$ = *distance from Earth's surface.*

Diameters of two Globes being equal, and their densities different, weight of a body on their surfaces will be as their densities.

Their densities being equal and their diameters different, weight of them will be as their diameters.

Diameters and densities being different, weight will be as their product.

Illustration.—If a body weighs 10 lbs. at surface of Earth, what will it weigh at surface of Sun, densities being 392 and 100, and diameters 8000 and 883 000 miles?

$\overline{883\,000 \times 100} \div \overline{8000 \times 392} = 28.157$ = *quotient of product of diameter of Sun and its density, and product of diameter of Earth and its density.*

Then $28.157 \times 10 = 281.57$ *lbs.*

Note.—Gravity of a body is .003 46 less at Equator than at Poles.

SPECIFIC GRAVITY AND WEIGHT.

Specific Gravity or Weight of a body is the proportion it bears to the weight of another body of known density or of equal volume, and which is adopted as a standard.

If a body float on a fluid, the part immersed is to whole body as specific gravity of body is to specific gravity of fluid.

When a body is immersed in a fluid, it loses such a portion of its own weight as is equal to that of the fluid it displaces.

An immersed body, ascending or descending in a fluid, has a force equal to difference between its own weight and weight of its bulk of the fluid, less resistance of the fluid to its passage.

Water is well adapted for standard of gravity; and as a cube foot of it ... F. *weighs* 997.68 ounces avoirdupois, its weight is taken as the unit ... *ximately* 1000.

ench standard temperature for comparison of density of solid bodies determination of their specific gravities, is that of maximum density of r, at 4° C. or 39.1° F., and for gases and vapors under one atmosphere or entimeters of mercury is 32° F. or 0° C., and specific gravity of a body pressed by weight in kilogrammes of a cube decimeter of that body.

ensities of metals vary greatly.

otassium, Sodium, Barium, and Lithium are lighter than water. Mercury aviest liquid and Platinum heaviest metal. Volcanic scoriæ is lighter water.

omegranate and Lignum-vitæ are heaviest of woods. Pearl is heaviest nimal substances, and Flax and Cotton are heaviest of vegetable subces, former weighing nearly twice as much as water.

rcon is heaviest of precious stones, being 4.5 times heavier than water. net is 4 times heavier, Diamond 3.5 times, and Opal, lightest of all, is but e as heavy as water.

Ascertain Specific Gravity of a Solid Body heavier than Water.

ULE.—Weigh it both in and out of water, and note difference; then, as ht lost in water is to whole weight, so is 1000 to specific gravity of body.

, $\frac{W \times 1000}{W - w} = G$, W *and w representing weights out and in water, and* G *fic gravity.*

AMPLE. —What is specific gravity of a stone which weighs in air 15 lbs., in r 10 lbs.?

$15 - 10 = 5$; then $5 : 15 :: 1000 : 3000$ *Spec. Grav.*

Ascertain Specific Gravity of a Body lighter than Water.

ULE.—Annex to lighter body one that is heavier than water, or fluid ; weigh piece added and compound mass separately, both in and out of r, or fluid; ascertain how much each loses, by subtracting its weight its weight in air, and subtract less of these differences from greater.

ien, as last remainder is to weight of light body in air, so is 1000 to fic gravity of body.

AMPLE.—What is specific gravity of a piece of wood that weighs 20 lbs. in air; ed to it is a piece of metal that weighs 24 lbs. in air and 21 lbs. in water, and wo pieces in water weigh 8 lbs.?

$20 + 24 - 8 = 44 - 8 = 36 =$ *loss of compound mass in water;*
$24 - 21 \qquad = 3 =$ *loss of heavy body in water.*
$33 : 20 :: 1000 : 606.06$ *Spec. Grav.*

To Ascertain Specific Gravity of a Fluid.

ULE.—Take a body of known specific gravity, weigh it in and out of luid; then, as weight of body is to loss of weight, so is specific gravity dy to that of fluid.

AMPLE. —What is specific gravity of a fluid in which a piece of copper (*spec.* $= 9000$) weighs 70 lbs. in, and 80 lbs. out of it?

$80 : 80 - 70 = 10 :: 9000 : 1125$ *Spec. Grav.*

Ascertain Specific Gravity of a Solid Body which is soluble in Water.

LE.—Weigh it in a liquid in which it is not soluble, divide it f the liquid by loss of its weight in the liquid, and multiply ecific gravity of liquid; the product is specific gravity.

MPLE.—What is specific gravity of a piece of clay, which weighs 15 lbs. in a *liquid of a specific gravity* of 1500, in which it is insoluble

$15 \div 10 \times 1500 = 2250$ *Spec. Grav.*

SOLIDS.

Substances.	Specific Gravity.	Weight of a Cube Inch.
		Lb.
Metals.		
Aluminum, cast........	2 560	.0926
" wrought....	2 670	.0906
" Bronze.....	7 700	.2785
Antimony..............	6 712	.2428
Arsenic................	5 763	.2084
Barium................	470	.017
Bismuth...............	9 823	.3553
Boron.................	2 000	.0723
Brass.		
Sheet, cop. 75, zinc 25.	8 450	.3056
Yellow " 66, " 34.	8 300	.2997
Muntz " 60, " 40.	8 200	.2966
Plate.................	8 380	.3026
Cast..................	8 100	.2930
Wire..................	8 214	.2972
Bromine...............	3 000	.1085
Bronze, gun metal......	8 750	.3165
" ordinary mean .	8 217	.2972
" cop. 84, tin 16..	8 832	.3194
" " 81, " 19..	8 700	.2929
" Tobin..........	8 379	.3021
" 35, tin 65.......	8 060	.291
" 21, tin 74.......	7 390	.2668
Cadmium..............	8 650	.3129
Calcium...............	1 580	.057
Chromium.............	5 900	.2134
Cinnabar..............	8 098	.2929
Cobalt................	8 600	.3111
Columbium............	6 000	.217
Copper, cast...........	8 608	.3113
" plates..........	8 698	.3146
" wire and bolts..	8 880	.3212
" ordinary mean.	8 880	.3212
Gold, pure, cast........	19 258	.6965
" hammered.......	19 361	.7003
" 22 carats fine.....	17 486	.6325
" 20 " "	15 709	.5682
Iridium................	18 680	.6756
" hammered......	23 000	.8319
Iron, Cast, gun metal...	7 308	.264
" minimum........	6 900	.2491
" maximum........	7 500	.2707
" ordinary mean....	7 207	.2607
" mean, Eng........	7 217	.2609
" cast, hot blast.....	7 065	.2555
" " cold "	7 218	.2611
" Wrought bars.....	7 788	.2817
" " wire.......	7 774	.2811
" " rolled plates	7 704	.2787
" " average....	7 698	.2779
" " Eng. rails..	7 540	.2722
" " Lowmoor...	7 808	.2819
" " pure.......	8 140	.2938
" ordinary mean....	7 744	.2801
Lead, cast.............	11 352	.4106
" rolled...........	11 388	.4119
Lithium...............	590	.0213
Magnesium............	1 750	.0633
anganese............	8 000	.2894
ry —40°.........	15 632	.5661
+32°.........	13 598	.4918

Substances.	Specific Gravity.
Metals.	
Mercury 60°.........	13 569
" 212°.........	13 370
Molybdenum...........	8 600
Nickel.................	8 800
" cast.............	8 279
Osmium...............	10 000
Palladium.............	11 350
Platinum, hammered...	20 337
" native.......	16 000
" rolled........	22 069
Potassium, 59°.........	865
Red lead...............	8 940
Rhodium..............	10 650
Rubidium.............	1 520
Ruthenium............	8 600
Selenium..............	4 500
Silver, pure, cast.......	10 474
" " hammered.	10 511
Sodium................	970
Steel, minimum........	7 700
" maximum........	7 900
" plates, mean.....	7 806
" soft.............	7 833
" temper'd and hardened..........	7 818
" wire............	7 847
" blistered.........	7 823
" crucible..........	7 842
" cast.............	7 848
" Bessemer........	7 852
" ordinary mean....	7 834
Strontium.............	2 540
Tellurium.............	6 110
Thallium..............	11 850
Tin, Cornish, hammered.	7 390
" " pure......	7 291
Titanium..............	5 300
Tungsten..............	17 000
Uranium...............	18 330
Wolfram...............	7 119
Zinc, cast..............	6 861
" rolled.............	7 191
Woods (*Dry*).	
Alder..................	800
Apple..................	793
Ash....................	845 690
Bamboo................	400
Baytree................	822
Beech..................	852 690
Birch..................	567 720
Blackwood, India......	898
Boxwood, Brazil........	1 031
" France.......	1 328
" Holland......	912
Bullet-wood...........	928
Butternut..............	376

...TANCES.	Specific Gravity.	Weight of a Cube Foot.
...ds (*Dry*).		Lbs.
...y............	913	57.062
....	561	35.062
...in............	1315	82.157
...pine..........	441	27.562
...resh burned..	380	23.75
...oak..........	1573	98.312
...soft wood....	280	17.5
...riturated....	1380	86.25
....	715	44.687
...sweet........	610	38.125
....	726	45.375
....	1040	65
....	240	15
...panish.......	644	40.25
....	756	47.25
...merican......	1331	83.187
...lian..........	1209	75.562
....	695	43.437
.... {	570	35.625
	671	41.937
....	800	50
...lia..........	1014	63.375
....	600	37.5
...y Spruce....	512	32
...ic...........	582	36.375
....	970	60.625
...; or Sipiri....	1055	65.95
....	843	52.687
...r............	1000	62.5
...k............	592	37
....	910	56.875
....	860	53.75
....	368	23
...ig-nut........	792	49.5
...hell-bark.....	690	43.125
....	760	47.5
....	990	61.875
....	770	48.125
....	566	35.375
...ia............	1171	73.187
..., mean......	720	45
.... {	544	34
	560	35
....	703	43.937
...se......... {	650	40.625
	1333	83.312
....	804	50.25
....	604	37.75
....	728	45.5
....	913	57.062
.... {	720	45
	1063	66.437
...Honduras....	560	35
...Spanish......	852	53.25
....	750	46.875
...s-eye........	576	36
....	849	53.062
.... {	561	35.062
	897	56.062
...n............	823	51.437
...lian.........	872	54.5
...ia...........	759	47.437

SUBSTANCES.	Specific Gravity.	Weight of a Cube Foot.
Woods (*Dry*).		Lbs.
Oak, English......... {	858	53.625
	932	58.25
" green............	1146	71.625
" heart, 60 years....	1170	73.125
" live, green........	1260	78.75
" " seasoned.....	1068	66.75
" white............	860	53.75
Olive..................	680	42.5
Orange................	705	44.062
Pear..................	661	41.312
Persimmon............	710	44.375
Plum..................	785	49.062
Pine, pitch............	660	41.25
" red..............	590	36.875
" white............	554	34.625
" yellow...........	461	28.812
" Norway..........	740	46.25
Pomegranate...........	1354	84.625
Poon..................	580	36.25
Poplar................	383	23.937
" white............	529	33.062
Quince................	705	44.062
Rosewood..............	728	45.5
Sassafras..............	482	30.125
Satinwood.............	885	55.312
Spruce................	500	31.25
Sycamore..............	623	38.937
Tamarack..............	383	23.937
Teak (African oak).... {	657	41.062
	980	61.25
Walnut................	671	41.937
" black...........	500	31.25
Willow............. {	486	30.375
	585	36.562
Yew, Dutch............	788	49.25
" Spanish..........	807	50.437
(Well Seasoned.)*		
Ash...................	722	45.125
Beech.................	624	39
Cherry................	606	37.875
Cypress...............	441	27.562
Hickory, red...........	838	52.375
Mahogany, St. Domingo.	720	45
Pine, white............	473	29.562
" yellow...........	541	33.812
Poplar................	587	36.687
White Oak, upland.....	687	42.937
" " James River	759	42.437
Stones, Earths, etc.		
Alabaster, white........	2730	170.625
" yellow......	2699	168.687
Alum..................	1714	107.125
Amber..........		67.375
Ambergris.......		—
Asbestos, starry.		[illegible].062
Asphalte.		[illegible]25
Barytes, sulphate		
Beton, N. Y. St. Co.		

* *U. S. Ordnance Manual*, 1841.

Substances.	Specific Gravity.	Weight of a Cube Foot.
		Lbs.
Stones, Earths, etc.		
Basalt	2740	171.25
	2864	179
Bitumen, red	1160	72.3
" brown.	830	51.7
Borax	1714	107.125
Brick	1367	85.437
	1900	118.75
" pressed	2400	150
" fire	2201	137.562
" work in cement	1800	112.5
" " " mortar.	1600	100
	2000	125
Carbon	3500	218.75
Cement, Portland	1300	81.25
" Roman	1560	97.25
Chalk.	1520	95
	2784	174
Clay	1930	120.625
" with gravel	2480	155
Coal, Anthracite	1350	84.375
	1436	89.75
	1640	102.5
" Borneo	1290	80.625
" Cannel	1238	77.375
	1318	82.375
" Caking	1277	79.812
" Cherry.	1276	79.75
" Chili	1290	80.625
" Derbyshire	1292	80.75
" Lancaster	1273	79.562
" Maryland	1355	84.687
" Newcastle	1270	79.375
" Rive-de Gier	1300	81.25
" Scotch	1259	78.687
	1300	81.25
" Splint	1302	81.375
" Wales, mean	1315	82.187
Coke	1000	62.5
" Nat'l, Va.	746	46.64
Concrete, in cement	2200	137.5
" mean	2000	125
Earth,* common soil, dry	1216	76
" loose	1500	93.75
" moist sand	2050	128.125
" mold, fresh	2050	128.125
" rammed	1600	100
" rough sand	1920	120
" with gravel	2020	126.25
" Potters'	1900	118.75
" light vegetable	1400	87.5
Emery	4000	250
Feldspar	2600	162.5
Flint, black	2582	161.375
" white	2594	162.125
Fluorine	1320	82.5
Fuel, Warlich's	1150	71.875
" Lignite	1300	81.25
Glass, bottle	2732	170.75
" *Crown*	2487	155.437
" *flint*	2933	183.312
	3200	196
Stones, Earths, etc.		
Glass, green	2642	165.125
" optical	3450	215.625
" white	2892	180.75
" window	2642	165.125
" soluble	1250	78.125
Gniess, common	270	15.875
Granite, Egyptian red	2654	165.875
" Patapsco	2640	165
" Quincy	2652	165.75
" Scotch	2625	164.062
" Susquehanna	2704	169
" " gray	2800	175
Graphite	2200	137.5
Gravel, common	1749	109.312
Grindstone	2143	133.937
Gypsum, opaque	2168	135.5
Hone, white, razor	2876	179.75
Hornblende	3540	221.25
Iodine	4940	—
Lava, Vesuvius	1710	106.875
	2810	175.625
Lias	1350	146.875
Lime, quick	804	50.25
" hydraulic	2745	171.562
Limestone, white	3156	197.25
" green	3180	198.75
Magnesia, carbonate	2400	150
Magnetic ore	5094	317.6
Marble, Adelaide	2715	169.687
" African	2708	169.25
" Biscayan, black.	2695	168.437
" Carrara	2716	169.75
" common	2686	167.875
" Egyptian	2668	166.75
" French	2649	165.562
" Italian, white	2708	169.25
" Parian	2838	177.375
" Vermont, white.	2650	165.57
" Silesian	2730	170.625
Marl, mean	1750	109.375
" tough	2340	146.25
Masonry, rubble	2050	128.125
" Granite	2640	165
" Limestone	2640	165
" Sandstone	2160	135
" Brick	2240	140
" " rough work	1600	100
Mica	2800	175
Millstone	2484	155.25
" Quartz	1260	78.75
Mortar	1384	86.5
	1750	109.375
Mud	1630	101.875
" wet and fluid	1782	112
" " " pressed	1920	120
Nitre	1900	118.75
Oyster-shell	2092	130.75
Paving-stone	2416	151
Peat, Irish, light	278	17.375
" " dense	562	35.125
" very "	675	42.18

* Specific gravity of earth is estimated at from 1520 to 2200.

SUBSTANCES.	Specific Gravity.	Weight of a Cube Foot.
		Lbs.
ones, Earths, etc.		
, black	1058	66.125
	1329	83.062
sphorus	1770	110.625
ter of Paris	1176	73.5
	3400	212.5
" " dry	1400	87.5
nbago	2100	131.25
elain, China	2300	143.75
hyry, red	2765	172.812
ice-stone	915	57.187
rtz	2660	166.25
lead	8940	558.75
n.	1089	68.062
k, crystal	2735	170.937
en-stone	1981	123.812
, common	2130	133.125
rock	2200	137.5
petre	2090	130.625
l, coarse	1800	112.5
common	1670	104.375
damp and loose	1392	87
dried " "	1560	97.5
dry	1420	88.75
mortar, Ft. Richm'd	1659	103.66
" Brooklyn	1716	107.25
silicious	1701	106.33
dstone, mean	2200	137.5
" Sydney	2237	139.81
orl	3170	198.125
ria, volcanic	830	51.875
er pipe, mean	2250	140.625
le.	2600	162.5
e	2672	167
	2900	181.25
purple	2784	174
lt.	2440	152.5
pstone	2730	170.625
r, calcareous	2735	170.937
Feld, blue	2693	168.312
" green	2704	169
Fluor	3400	212.5
ular ore	5251	328.187
ctite	2415	150.937
e, Bath, Engl.	1961	122.562
Blue Hill	2640	165
Bluestone (basalt)	2625	164.062
Breakneck, N.Y.	2704	169
Bristol, Engl.	2510	156.875
Caen, Normandy	2076	129.75
common	2520	157.5
Craigleith, Scotl.	2316	144.75
Kentish rag. "	2651	165.687
Kip's Bay, N.Y.	2759	172
Norfolk (Parliament House)	2304	144
Portland, Engl.	2368	148
Staten Isl'd, N.Y.	2976	186
Sullivan Co., "	2688	168
ur, native	2033	127.062
Cotta	1952	122
	1815	113.437
	2720	170

SUBSTANCES.	Specific Gravity.	Weight of a Cube Foot.
		Lbs.
Granite.		
(Gen'l Gillmore, U. S. A.)		
Duluth, Minn., dark	2780	173.7
Fall River, Mass., gray	2635	164.7
Garrison's, N. Y. "	2580	161.2
Jersey City, N. J., soap	3030	189.3
Keene, N. H., bluish gray	2656	166
Maine	2635	164.7
Millstone Pt., Conn.	2706	169.1
New London, "	2660	166.25
Quincy, Mass., light	2695	168.5
Richmond, Va.	2727	170.5
" " gray	2630	164.4
Staten Island, N. Y.	2861	178.8
Westchester Co., N. Y.	2655	165.9
Westerly, R. I., gray	2670	166.9
Limestone.		
(Gen'l Gillmore, U. S. A.)		
Bardstown, Ky., dark	2670	166.9
Caen, France	1900	118.8
Canajoharie, N. Y.	2685	167.8
Cooper Co., Mo., d'k drab	2320	141.3
Erie Co., N. Y., blue	2640	165
Garrison's, N. Y.	2635	164.7
Glens' Falls, "	2700	168.7
Joliet, Ill., white	2540	158.7
Kingston, N. Y.	2690	168.1
Lake Champlain, N. Y.	2750	171.9
Lime Island, Mich., drab	2500	156.3
Marblehead, Ohio, white	2400	150
Marquette, Mich., drab	2340	146.25
Sturgeon Bay, Wis., bluish drab	2780	173.7
Marble.		
(Gen'l Gillmore, U. S. A.)		
Dorset, Vt.	2635	164.7
East Chester, N. Y.	2875	179.7
Italian, common	2690	168.1
Mill Creek, Ill., drab	2570	171.9
North Bay, Wis., "	2800	175
Sandstone.		
(Gen'l Gillmore, U. S. A.)		
Albion, N.Y., brown	2420	151.25
Belleville, N. J., gray	2259	141.2
Berea, Ohio, drab	2110	131.9
Cleveland, " olive green	2240	140
Edinb'h, Sc'tl., Craigleith	2260	141.25
Fond du Lac, Wis., purple	2220	138.7
Fontenac, Minn., l'g't buff	2325	145.31
Haverstraw, N. Y., red	2130	133.1
Kasota, Minn., pink	[illegible]	164.375
Little Falls, N. Y., br		140.6
Marquette, Mich., p		142.5
Masillon, O., yellow		.87
Medina, N. Y., pink		
Middletown, Ct., b		
Seneca, Ohio, red		
Vermillion, Ohio, d		
Warrensburgh, Mo.		

Precious Stones.

	Spec. Grav.
Agate	2590
Amethyst	3920
Carnelian	2613
Chrysolite	2782
Diamond, Oriental	3521
" Brazilian	3444
" pure	3520
Emerald	3950
Emerald, aqua marine	2730
Garnet	4189
" black	3750
Jasper	2600
Jet	1300
Lapis lazuli	2960
Malachite	4020
Onyx	2700
Opal	2090
Pearl, Oriental	2650
Ruby	3980
Sapphire	3994
Topaz	3500
Tourmaline	3070
Turquoise	2750

SUBSTANCES.	Specific Gravity.	Weight of a Cube Foot.
		Lbs.
Miscellaneous.		
Amber	1090	68.125
Atmospheric Air	.001292	.080728
Beeswax	965	60.312
Bone	1900	118.75
Butter	942	58.875
Camphor	988	61.75
Caoutchouc	930	58.125
Cotton	950	59.375
Dynamite	1650	103.125
Egg	1090	—
Fat of Beef	923	57.687
" Hogs	936	58.5
" Mutton	923	57.687
Flax	1790	111.875
Gamboge	1222	—
Glycerine, 60°	1261	78.752
Grain, Barley	590	36.875
" Wheat	750	46.875
" Oats	500	31.25
Gum Arabic	1452	90.75
Gunpowder, loose	900	56.25
" shaken	1000	62.5
" solid	1550	96.875
	1800	112.5
Gutta-percha	980	61.25
Hay, old compact	128.8	8.05
Horn	1689	105.562
Human body	1070	66.935
Ice, at 32°	922	57.5
Indigo	1009	63.062
Isinglass	1111	69.437
Ivory	1825	114.062
Lard	947	59.187
Leather	960	60
Mastic	1074	67.125
Myrrh	1360	85
Nitro-Glycerine	1600	100
Opium	1336	83.5
Potash	2100	131.25
Resin	1089	68.062
Snow	.0833	5.2
Soap, Castile	1071	66.937
Spermaceti	943	58.937
Starch	950	59.375
Sugar	1606	100.375
" .66	972	60.25
	1326	82.875
Tallow	941	58.812
	964	60.25
	970	60.625

SUBSTANCES.	Specific Gravity.	Weight of a Cube Foot.
		Lbs.
Liquids.		
Acid, Acetic	1062	66.375
" Benzoic	667	41.687
" Citric	1034	64.625
" Concentrated	1521	95.062
" Fluoric	1500	93.75
" Muriatic	1200	75
" Nitric	1217	76.062
" Nitrous	1550	96.875
" Phosphoric	1558	97.375
" " solid	2800	175
" Sulphuric	1849	115.562
Alcohol, pure, 60°	794	49.625
" 95 per cent	816	51
" 80 "	863	53.937
" 50 "	934	58.375
" 40 "	951	59.437
" 25 "	970	60.625
" 10 "	986	61.625
" 5 "	992	62
" proof spirit,* 50 per cent., 60°	934	58.375
" proof spirit, 50 per cent., 80°	875	54.687
Ammonia, 27.9 per cent	891	55.687
Aquafortis, double	1300	81.25
" single	1200	75
Beer	1034	64.625
Benzine	850	53.125
Bitumen, liquid	848	53
Blood (human)	1054	65.875
Brandy, .83 or .5 of spirit	924	57.75
Bromine	2966	185.375
Cider	1018	63.625
Ether, Acetic	866	54.125
" Muriatic	845	52.812
" Nitric	1110	69.375
" Sulphuric	715	44.687
Honey	1450	90.625
Milk	1032	64.5
Oil, Anise-seed	986	61.625
" Codfish	923	57.687
" Whale	923	57.687
" Linseed	940	58.75
" Naphtha	850	53.125
" Olive	915	57.187
" Palm	969	60.562
" Petroleum	880	5[illegible]
" Rape	914	
" Sunflower	926	
" Turpentine	870	

* [illegible] gravity of proof spirit according to Ure's Table for Sykes's Hydrometer, [illegible]

Substances.	Specific Gravity.	Weight of a Cube Foot.	Substances.	Specific Gravity.	Weight of a Cube Foot.
Liquids.		Lbs.	**Liquids.**		Lbs.
rit, rectified	824	51.5	Water, Dead Sea	1240	77.5
am, at 212°	.00061	.038*	" Mediterranean	1029	64.312
	1015	63.437	" sea	1029	64.312
egar	1080	67.5	" Black Sea	1016	63.5
ter, at 32°	998.7	62.418	" rain	1000	62.5
" " 39.1°	998.8	62.425	Wine, Burgundy	992	62
" " 62°†	997.7	62.355	" Champagne	997	62.312
" " 212°	956.4	59.64	" Madeira	1038	64.375
" distilled, at 39°	998	62.379	" Port	997	62.312

* .038 18. † 1 cube inch at standard temperature = 252.5954 grains.

ompression of following fluids under a pressure of 15 lbs. per square inch:

ohol. . .000 021 6 | Mercury. . .000 002 65 | Water. . .000 046 63 | Ether. . .000 061 58

Elastic Fluids.

ube Foot of Atmospheric Air at 32° weighs .080 728 lbs. Avoirdupois = 565.096 grains, and at 62° 532.679 grains.

Its assumed Gravity of 1 is Unit for Elastic Fluids.

	Spec. Grav.		Spec. Grav.		Spec. Grav.
tic Ether	3.04	Nitric acid	1.217	Vapor.	
monia	.589	" oxide	1.094	Alcohol	1.613
ios. air, at 32°	1	Nitrogen	.974	Bisulphuret of Carbon	2.64
te	.976	Nitrous acid	2.638	Bromine	5.4
onic acid	1.53	Nitrous oxide	1.527	Chloric Ether	3.44
" oxide	.972	Olefiant gas	.9672	Chloroform	4.2
uret'd Hydrog.	.559	Oxygen	1.106	Ether	2.586
rine	2.421	Phosphurett'd Hydrogen	1.77	Hydrochlor. Ether	2.255
ro-carbonic	3.389	Sulphuretted Hydrogen	1.17	Iodine	8.716
roform	5.3	Sulphurous acid	2.21	Nitric acid	3.75
ogen	1.815	Steam,‡ at 212°	.47295	Spirits of Turpentine	5.013
coal	.438 / .752	Smoke.		Sulphuric acid	2.7
rochloric acid	1.278	Bitum. Coal	.102	" Ether	2.586
rocyanic "	.942	Coke	.105	Sulphur	2.214
rogen	.0692	Wood	.09	Water	.623
atic acid	1.247				

‡ eight of a cube foot 267.26 *grains*, and compared with water at 62° specific gravity = .000 612 3.

ght of a Cube Foot of Gases at 32° F., and under Pressure of one Atmosphere, or 2116.4 lbs. per Square Foot.

	Lbs.		Lbs.		Lbs.
at 32°	.080 728	Chlorine	.197	Hydrogen	.005 594
" 62°	.076 097	Chloroform	.428	Nitrogen	.078 596
ol	.130 2	Coal gas	.035 36	Olefiant gas	.079 5
nic acid	.123 44	Ether, Sulphuric	.209 3	Oxygen	.089 256
ret. Hydrog.	.044 62	Gaseous steam	.050 22	Steam	.050 22

Sulphurous acid . . . . . . .1814 lbs.

Compute Weight of a Body or Substance when Specific Gravity is given.

LE.—Multiply specific gravity by unit or stand or sube, and product is the weight.

Divide specific gravity of body or substance by ill weight of a cube foot of it in lbs.

MPLE.—*Specific gravity is 2250;* what is weight of a cu

2250 × 62.5 = 140.625 lbs.

Weights and Volumes of various Substances in Ordinary Use.

Substances.	Cube Foot.	Cube Inch.
Metals.	Lbs.	Lbs.
Brass.. { copper 67 / zinc 33 }	488.75	.2829
" gun metal.	543.75	.3147
" sheets.....	513.6	.297
" wire......	524.16	.3033
Copper, cast.........	547.25	.3179
" plates.......	543.625	.3167
Iron, cast...........	450.437	.2607
" gun metal......	466.5	.27
" heavy forging..	479.5	.2775
" plates.........	481.5	.2787
" wrought bars...	486.75	.2816
Lead, cast...........	709.5	.4106
" rolled.........	711.75	.4119
Mercury, 60°.........	848.7487	.491174
Steel, plates.........	487.75	.2823
" soft...........	489.562	.2833
Tin..................	455.687	.2637
Zinc, cast...........	428.812	.2482
" rolled..........	449.437	.2601
Woods.		Cube Feet in a Ton.
Ash..................	52.812	42.414
Bay..................	51.375	43.601
Blue Gum.............	64.3	34.837
Cork.................	15	149.333
Cedar................	35.062	63.886
Chestnut.............	38.125	58.754
Hickory, pig-nut.....	49.5	45.252
" shell-bark..	43.125	51.942
Lignum-vitæ..........	83.312	26.886
Logwood..............	57.062	39.255
Mahoga'y, Hondur's {	35	64
	66.437	33.714
Oak, Canadian........	54.5	41.101
" English........	58.25	38.455
" live, seasoned...	66.75	33.558
" white, dry......	53.75	41.674
" " upland...	42.937	52.169
Pine, pitch..........	41.25	54.303
" red............	36.875	60.745
" white..........	34.625	64.693
" well seasoned..	29.562	75.773
Pine, yellow.........	33.812	66.248

Substances.	Cube Foot.	Cube Feet in a Ton.
Woods.	Lbs.	
Spruce...............	31.25	71.68
Walnut, black, dry...	31.25	71.68
Willow...............	36.562	61.265
" dry..........	30.375	73.744
Miscellaneous.		
Air..................	.075291	—
Basalt, mean.........	175	12.8
Brick, fire..........	137.562	16.284
" mean.........	102	21.961
Coal, anthracite.... {	89.75	24.958
	102.5	21.854
" bitumin., mean.	80	28
" Cannel.........	94.875	23.609
" Cumberland....	84.687	26.451
" Welsh, mean...	81.25	27.569
Coke.................	62.5	35.84
Cotton, bale, mean...	14.5	154.48
" " pressed {	20	114
	25	89.6
Earth, clay..........	120.625	18.569
" common soil..	137.125	16.335
" " gravel	109.312	20.48
" dry, sand.....	120	18.667
" loose.........	93.75	23.893
" moist, sand...	128.125	17.482
" mold.........	128.125	17.482
" mud..........	101.875	21.987
" with gravel...	126.25	17.749
Granite, Quincy......	165.75	13.514
" Susquehanna	169	13.254
Gypsum...............	135.5	16.531
Hay, bale............	12	186.66
" hard pressed....	25	89.6
Ice, at 32°..........	57.5	38.95
India rubber.........	56.437	39.69
" " vulcanized	—	—
Limestone............	197.25	11.355
Marble, mean.........	167.875	13.343
Mortar, dry, mean....	97.98	22.863
Plaster of Paris......	73.5	30.476
Water, rain..........	62.5	35.84
" salt..........	64.312	34.83
" at 62°........	62.355	35.955

	Cube foot.	Cube inch.
Metals.—Tobin Bronze..........	522.02 lbs.	.3021 lbs.

To Compute Proportions of Two Ingredients in a Compound, or to Discover Adulteration in Metals.

RULE.—Take differences of each specific gravity of ingredients and specific gravity of compound, then multiply gravity of one by difference of ...er; and, as sum of products is to respective products, so is specific ...vity of body to proportions of the ingredients.

...MPLE.—A compound of gold (*spec. grav.* = 18.888) and silver (*spec. grav.* = ...) ... specific gravity of 14; what is proportion of each metal?

...10.535 = 51.495. 14 − 10.535 = 3.465 × 18.888 = 65.447.
...:14 : 7.835 gold, 65.447 + 51.495 : 51.495 :: 14 : 6.165 silver.

ights of Various Substances per Cube Foot in Bulk.

	Lbs.		Lbs.		Lbs.
in pigs.........	567	Potters' clay.......	130	Coal, caking..........	50
"	360	Loam..............	126	Wheat..............	48
.e, in blocks } stone, " } ..	172	Gravel.............	109	Barley..............	38
		Sand..............	95	Fruit and vegetables..	22
....	170	Bricks, common....	93	Cotton seeds..........	12
te, in blocks....	164	Ice, at 32°.........	57.5	Cotton..............	10
stone...........	141	Oak, seasoned......	52	Hay, old............	8

iry, 100 feet BM....	.175 ton.	Earth, loose..............	93.75 lbs.
white, " "	.141 "	Elm, dry, 100 feet BM.....	.13 ton.
nt, struck bushel and packed*........100 lbs.		Gypsum, ground, str. bush.	70 lbs.
		" " well shaken	80 "
nt, Portland, bushel. 110 lbs.		Hemlock, dry, 100 feet BM.	.093 ton.
y, dry, 100 BM.....	.156 ton.	Hickory, " " " .	.197 "
nut, dry, 100 BM...	.153 "	Masonry, Granite, dressed..	165 lbs.
anthracite, 1 cub. yd.		" " rough...	126 "
broken and loose...	1.75 yds.	" Limestone, dres'd	165 "
" " 1 ton..	41.5 cub. feet.	" Sandstone.......	135 "
ton = ...80 to 97 cub. feet.		" Brick, pressed...	140 "
, common soil......137.125 lbs.		" " com'n, rough.	100 "

* One packed bushel = 1.43 loose.

parative Weight of Green and Seasoned Timber.

Timber.	Weight of a Cube Foot. Green.	Seasoned.	Timber.	Weight of a Cube Foot. Green.	Seasoned.
	Lbs.	Lbs.		Lbs.	Lbs.
ican Pine......	44.75	30.7	Cedar.............	32	28.25
....	58.18	50	English Oak.......	71.6	43.5
l.............	60	53.37	Riga Fir...........	48.75	35.5

Application of the Tables.

hen Weight of a Solid or Liquid Substance is required. Rule.—Ascer- volume of substance in cube feet; multiply it by unit in second column bles (its specific gravity), and divide product by 16; quotient will give ht in lbs.

hen Volume is given or ascertained in Inches. Rule.—Multiply it by in third column of tables (weight of a cube inch), and product will give ht in lbs.

mple.—What is weight of a cube of Italian marble, sides being 3 feet?

$$3^3 \times 2708 = 73\,116\ oz., \text{ which} \div 16 = 4569.75\ lbs.$$

of a sphere of cast iron 2 inches in diameter?

$$2^3 \times .5236 \times .2607\ \textit{weight of a cube inch} = 1.092\ lbs.$$

hen Weight of an Elastic Fluid is required. Rule.—Multiply specific ty of fluid by 532.679 (weight of a cube foot of air at 62° in grains), product by 7000 (grains in a lb. Avoirdupois), and quotient will give t of a cube foot in lbs.

mple.—What is weight of a cube foot of hydrogen?

ific gravity of hydrogen .0692.

$$532.679 \times .0692 \div 7000 = .005\,265\,9\ lbs.$$

ompute Weight of Cast Metal by Weig rn.

n Pattern is of White Pine. Rule.—Multiply wei n in following multipliers, and product will give weight , 14; Brass, 15; Lead, 22; Tin, 14; Zinc, 13.5.

n there are Circular Cores or Prints. Multiply squ r *print by its length* in inches, the product by .o *of pattern of core or print* to be deducted from weig

T

To Compute Weights of Ingredients, that of Compound being given.

RULE.—As specific gravity of compound is to weight of compound, so are each of the proportions to weight of its material.

EXAMPLE.—Weight, as p. 216, being 28 lbs., what are weights of the ingredients?

$$14 : 28 :: \begin{cases} 7.835 : 15.67 \textit{ gold}, \\ 6.165 : 12.33 \textit{ silver}. \end{cases}$$

NOTE.—Specific gravity of alloys does not usually follow ratio of their components, it being sometimes greater and sometimes less than their mean.

To Compute Capacity of a Balloon.

RULE.—From specific gravity of air in grains per cube foot, subtract that of the gas with which it is inflated; multiply remainder by volume of balloon in cube feet; divide product by 7000, and from quotient subtract weight of balloon and its attachments.

EXAMPLE.—Diameter of a balloon is 26.6 feet, its weight is 100 lbs., and specific gravity of the gas with which it is inflated is .07 (air being assumed at 1); what is its capacity, specific gravity of air assumed at 527.04 grains.

$$\frac{527.04 - (527.04 \times .07) \times 26.6^3 \times .5236}{7000} - 100 = 590.04 \textit{ lbs.}$$

To Compute Diameter of a Balloon.

Weight to be raised being given.—By inversion of preceding rule.

$$\sqrt[3]{\frac{W \div 7000 \div \overline{s \div s'}}{.5236}} = d.$$ *s and s representing weight of air and gas in grains per cube foot,* W *weight to be raised in lbs., and d diameter of balloon in feet.*

ILLUSTRATION.—Given elements in preceding case.

$$\text{Then } \sqrt[3]{\frac{\overline{590.04 + 100} \times 7000 \div \overline{527.04 - 36.89}}{.5236}} = \sqrt[3]{\frac{9854.69}{.5236}} = 26.6 \textit{ feet.}$$

Proof of Spirituous Liquors.

A cube inch of *Proof Spirits* weighs 234 grains; then, if an immersed cube inch of any heavy body weighs 234 grains less in spirits than air, it shows that the spirit in which it was weighed is *Proof.*

If it lose less of its weight, the spirit is above proof; and if it lose more, it is below proof.

ILLUSTRATION.—A cube inch of glass weighing 700 grains weighs 500 grains when weighed in a certain spirit; what is the proof of it?

$700 - 500 = 200 =$ *grains = weight lost in spirit.*

Then $200 : 234 :: 1 : 1.17 =$ *ratio of proof of spirits compared to proof spirits, or* $1 = .17$ *above proof.*

NOTE.—For Hydrometers and Rules for ascertaining Proof of Spirits, see page 67; and for a very full treatise on Specific Gravities and on Floatation, see Jameson's Mechanics of Fluids. Lond., 1837.

Shrinkage of Castings.

It is customary, in making of patterns for castings, to allow for shrinkage per lineal foot of pattern as follows:

Iron, small cylinders . . .	$= \frac{1}{16}$ in. per ft.	Ditto in length. . . .	$= \frac{1}{8}$ in 16 ins.
" Pipes	$= \frac{1}{8}$ "	Brass, thin.	$= \frac{1}{8}$ in 9 ins.
" Girders, beams, etc.	$= \frac{1}{8}$ in 15 ins.	" thick.	$= \frac{1}{8}$ in 10 ins.
[illegible]nders, [illegible]tion [illegible]op.	$= \frac{1}{16}$ per foot.	Zinc.	$= \frac{5}{16}$ in a foot.
		Lead	$= \frac{5}{16}$ "
		Copper.	$= \frac{3}{16}$ "
[illegible] . .	$= \frac{1}{12}$ "	Bismuth	= [illegible] "

GEOMETRY.

Definitions.

Point has position, but not magnitude.
Line is length without breadth, and is either *Right*, *Curved*, or *Mixed*.
Right Line is shortest distance between two points.
Curved Line is one that continually changes its direction.
Mixed Line is composed of a right and a curved line.
Superficies has length and breadth only, and is plane or curved.
Solid has length, breadth, and thickness, or depth.

Angle is opening of two lines having different directions, and is either *ht*, *Acute*, or *Obtuse*.
Right Angle is made by a line perpendicular to another falling upon it.
Acute Angle is less than a right angle.
Obtuse Angle is greater than a right angle.

Triangle is a figure of three sides.
Equilateral Triangle has all its sides equal.
Isosceles Triangle has two of its sides equal.
Scalene Triangle has all its sides unequal.
Right-angled Triangle has one right angle.
Obtuse-angled Triangle has one obtuse angle.
Acute-angled Triangle has all its angles acute.
Oblique-angled Triangle has no right angle.

Quadrangle or *Quadrilateral* is a figure of four sides, and has following ticular designations—viz.,
Parallelogram, having its opposite sides parallel.
Square, having length and breadth equal.
Rectangle, a parallelogram having a right angle.
Rhombus or *Lozenge*, having equal sides, but its angles not right angles.
Rhomboid, a parallelogram, its angles not being right angles.
Trapezium, having unequal sides.
Trapezoid, having only one pair of opposite sides parallel.
OTE.—Triangle is sometimes termed a Trigon, and a Square a Tetragon.

nomon is space included between the lines forming two similar parallelo- ns, of which smaller is inscribed within larger, so as to have one angle ach common to both.

olygons are plane figures having more than four sides, and are either *ular* or *Irregular*, according as their sides and angles are equal or un- il, and they are named from number of their sides or angles. Thus:

Pentagon	has	five sides.	Nonagon	has	nine sides.
Hexagon	"	six "	Decagon	"	ten "
Heptagon	"	seven "	Undecagon	"	eleven "
Octagon	"	eight "	Dodecagon	"	twelve "

rcle is a plane figure bounded by a curved line, termed *Circumference* *eriphery*.
ameter is a right line passing through centre of a circle or sphere, and inated at each end by periphery or surface.
c is any part of circumference of a circle.
ord is a right line joining extremities of an arc.
gment of a circle is any part bounded by an arc and
dius of a circle is a line drawn from centre to circu
tor is any part of a circle bounded by an arc and it
nicircle is half a circle.
adrant is a quarter of a circle.
e is a part of a circle included between two parallel
is space between the intersecting arcs of two ecce
L.

Secant is line running from centre of circle to extremity of tangent of arc.

Cosecant is secant of complement of an arc, or line running from centre of circle to extremity of cotangent of arc.

Sine of an arc is a line running from one extremity of an arc perpendicular to a diameter passing through other extremity, and sine of an angle is sine of arc that measures that angle.

Versed Sine of an arc or angle is part of diameter intercepted between sine and arc.

Cosine of an arc or angle is part of diameter intercepted between sine and centre.

Coversed Sine of an arc or angle is part of secondary radius intercepted between cosine and circumference.

Tangent is a right line that touches a circle without cutting it.

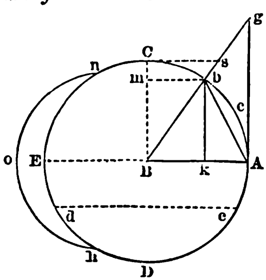
Cotangent is tangent of complement of arc.

Circumference of every circle is supposed to be divided into 360 equal parts, termed *Degrees;* each degree into 60 *Minutes*, and each minute into 60 *Seconds*, and so on.

Complement of an angle is what remains after subtracting angle from 90 degrees.

Supplement of an angle is what remains after subtracting angle from 180 degrees.

To exemplify these definitions, let A *c b, in following Figure, be an assumed arc of a circle described with radius* B A:



A *c b*, an Arc of circle A C E D.
A *b*, Chord of that arc.
B A, an Initial radius.
B C, a Secondary radius.
e D *d*, a Segment of the circle.
A B *b*, a Sector.
A D E, a Semicircle.
C B E, a Quadrant.
A *e d* E, a Zone.
n o h, a Lune.
B *g*, Secant of arc A *c b*; written Sec.
b k, Sine of arc A *c b*; written Sin.
A *k*, Versed Sine of arc A *c b*; written Versin.
B *k* or *m b*, Cosine of arc A *c b*.
A *g*, Tangent of arc A *c b*.
C B *b*, Complement, and *b* B E, Supplement of arc A *c b*.

C *s*, *Cotangent* of arc, written Cot. B *s*, *Cosecant* of arc; written Cosec.
m C, *Coversed sine* of arc, or, by convention, of angle A B *b*; written Coversin.

Vertex of a figure is its top or upper point. In Conic Sections it is point through which generating line of the conical surface always passes.

Altitude, or height of a figure, is a perpendicular let fall from its vertex [illegible] opposite side, termed base.

[illegible]sure of an angle is an arc of a circle contained between the two lines [illegible] the [illegible] estimated by number of degrees in arc.

[illegible] is [illegible] plane, parallel to base.

[illegible] is [illegible] after segment is cut off.

[illegible] of a [illegible] m of all its sides.

[illegible] d to be done.

[illegible] d.

[illegible] o be demonstrated.

[illegible] render what follows more easy.

[illegible] on a preceding demonstration.

[illegible] ng going before it.

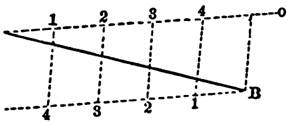
[illegible] f Surfaces and Solids, and Conic Sec[illegible]

Lengths of following Elements, Radius = 1.

	Angle 45°.	Angle 60°.		Angle 45°.	Angle 60°.
... .	.707 107	.866 025	Cosecant.....	1.414 214	1.154 7
...ne	.707 107	.5	Tangent.....	1	1.732 05
...sed Sine..	.292 893	.5	Cotangent ...	1	.577 349
...ersed " ..	.292 893	.133 975	Chord.......	.765 366	1
...nt	1.414 214	2	Arc.........	.785 398	1.047 2

Scales.

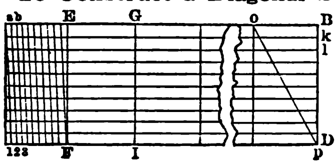
Divide a Line, as A B, with any required Number of Equal Parts.—Fig. 1.



From A and B draw two parallel lines, A *o*, B *r*, to an indefinite length, and upon them point off required number of equal parts, as A 1, 2, 3, 4, and B 1, 2, 3, 4; join *o* B, 4 1, etc.

Or, point off on A *o*, join *o* B, and draw the other lines parallel thereto.

To Construct a Diagonal Scale, as A B.—Fig. 2.



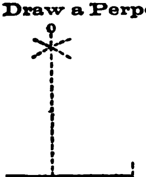
Divide a line into as many divisions as there are hundreds of feet, spaces of ten feet, feet, or inches required.

Draw perpendiculars from each division to a parallel line, C D. Divide one of divisions, A E, C F, into spaces of ten if for feet and hundredths, and twelve if for feet and inches; draw the lines A 1, ...b 3, etc., and they will complete scale.

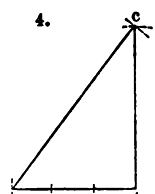
...*us*: Line A B representing ten feet; A to E, E to G, etc., will measure one ... A to *a*, C to 1, 1 to 2, etc., will measure 1-10th of a foot. The several lines ...*a* 2, etc., will measure upon lines *k*, *l*, etc., 1-100th of a foot; and *o p* will ...ure upon *k*, *l*, etc., divisions of 1-10th of a foot.

Lines.

Draw a Perpendicular to a Right Line, as *o r*, Fig. 3, *c* A, Fig. 4, or from a Point external to it, as A, Fig. 5, and from any two Points, as *c d*, Fig. 6.



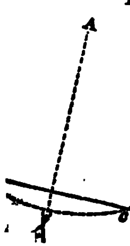
4.



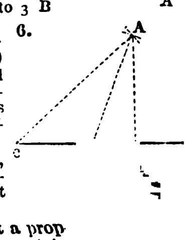
With any radius as *r* A, *r* B, cut line at A and B; then with a longer radius, as A *o*, B *o*, describe arcs cutting each other at *o*, and connect *o r*. (Fig. 3.)

Or, from A, set off A B equal to 3 parts by scale; from A B, with radii of 4 and 5 parts, describe arcs cutting at *c*, and connect *c* A. (Fig. 4.)

NOTE.—This method is useful where straight edges are inapplicable. Any multiples of numbers 3, 4, 5 may be taken with same effect, as 6, 8, 10, or 9, 12, 15.



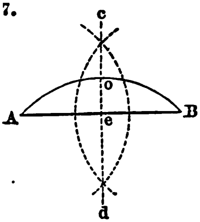
6.



From A, with a sufficient radius, cut line at *o c*, and from them describe arcs cutting at *r*, and connect A *r*. (Fig. 5.)

From any two points, as c *d, at a prop... distance apart*, describe arcs cutting at A ... *and connect them*. (Fig. 6.)

7.

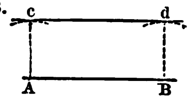


To Bisect a Right Line or an Arc of a Circle, and to Draw a Perpendicular to a Circular or Right Line, or a Radial Arc.—Fig. 7.

From A B as centres describe arcs cutting each other at *c* and *d*, connect *c d*, and line and arc are bisected at *e* and *o*.

Line *c d* is also perpendicular to a right line as A B, and radial to a circular arc as A *o* B.

8.



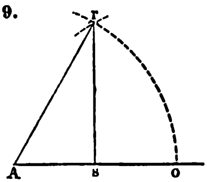
To Draw a Line Parallel to a Given Right Line, as c d, Fig. 8.

From A B describe arcs A *c*, B *d*, and draw a line parallel thereto, touching arcs *c* and *d*.

Angles.

To Describe Angles of 30° and 60°, Fig. 9, and 45°, Fig. 10.

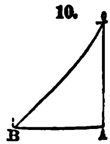
9.



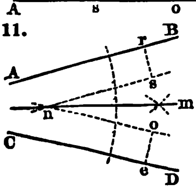
From A, with any radius, A *o*, describe *o r*, and from *o* with a like radius cut it at *r*, let fall perpendicular *r s*; then *o* A *r* = 60°, and A *r s* = 30°. (Fig. 9.)

Set off any distance, as A B, erect perpendicular A *o* = A B, and connect *o* B. (Fig. 10.)

10.



11.



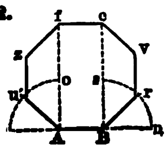
To Bisect Inclination of Two Lines, when Point of Intersection is Inaccessible.—Fig. 11.

Upon given lines, A B, C D, at any points draw perpendiculars *e o*, *s r*, of equal lengths, and from *o* and *s* draw parallels to their respective lines, cutting at *n*; bisect angle *o n s*, connect *n m*, and line will bisect lines as required.

Rectilineal Figures.

To Describe an Octagon upon a Line, as A B.—Fig. 12.

12.



From points A B erect indefinite perpendiculars A *f*, B *e*; produce A B to *m* and *n*, and bisect angles *m* A *o* and *n* B *s* with A *u* and B *r*.

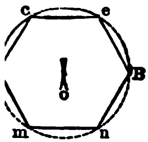
Make A *u* and B *r* equal to A B, and draw *u z*, *r v* parallel to A *f*, and equal to A B.

From *z* and *v*, as centres, with a radius equal to A B, describe arcs cutting A *f*, B *e*, in *f* and *e*. Connect *z f*, *f e*, and *e v*.

To Inscribe any Regular Polygon in a Circle, or to Divide Circumference into a given Number of Equal Parts.—Fig. 13.

Circle is to contain a Heptagon. — Draw angle A *o* B at ... for $360° \div 7 = 51° 42' 51''+$, or $51\frac{3}{7}$, then set off upon ... distance A B or remaining angles A *o* B.

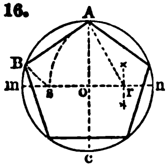
› Inscribe a Hexagon in a Circle.—Fig. 14.



Draw a diameter, A o B. From A and B as centres, with A o and B o, cut circle at c m and e n, and connect.

To Inscribe a Pentagon in a Circle.—Fig. 16.

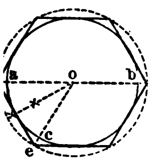
16.



Draw diameters A c and m n, at right angles to each other; bisect o n in r, and with r A describe A s; from A with A s describe s B.

Connect A B, and distance is equal to one side of a pentagon.

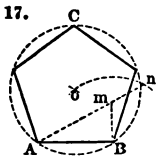
ɔ Describe a Hexagon ıbout a Circle.—Fig. 15.



Draw a diameter as a o b; and with a o cut circle at c; join a c, and bisect it with radius o r, through r draw e r parallel to c a, cutting diameter at m; then with radius lescribe circle, within which describe xagon as above.

To Describe a Pentagon upon a Line, as A B.—Fig. 17.

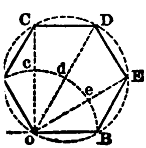
17.



Draw B m perpendicular to A B, and equal to one half of it; extend A m until m n is equal to B m.

From A and B, with radius B n, describe arcs cutting each other in o; then from o, with radius o B, describe circle A C B, and line A B is equal to one side of a pentagon upon circle described.

Describe a Regular Polygon of any required Number of Sides.—Fig. 18.



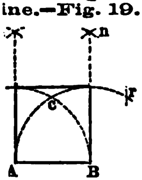
From point o, with distance o B, describe semicircle B b A, which divide into as many equal parts, A a, a b, b c, etc., as the polygon is to have sides.

Thus, let a Hexagon be required:

From o to second point b of six divisions draw o b, and through other points, c, d, and e, draw o C, o D, etc.

Apply distance o B, from B to E, from E to D, from D to C, etc. Join these points, as b C, C D, etc.

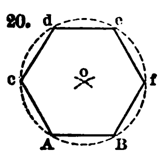
Construct a Square or Rectangle on a given ine.—Fig. 19.



On A B as centres, with A B as radius, describe arcs cutting at c; on c describe arcs cutting at o r; and on o r describe others, cutting at m n; draw A m and ıd join o r.

To Construct a Hexagon upon a given Line.—Fig. 20.

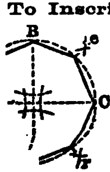
20.



From ends of line, A B, describe arcs cutting each other at o, and from o as a centre, with radius o A, describe a circle, and with same radius set off A c, c d, B f, f e, and connect them.

To Inscribe an Octagon in a Circle.—Fig. 21.

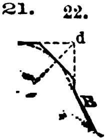
22.



Draw diameters, A C, B D, at right angles, bisect arcs, A B, B C, etc., at s, r, o, e, and join A o, o B, etc. (Fig. 21.)

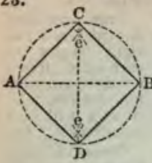
To Describe an Octagon about a Circle.—Fig. 22.

Describe a square about circle A B, draw diagonals c f, e d, draw o i, etc., *perpendicular to* diagonals and touching *circle.* (*Fig.* 22.)



To Inscribe a Square in a Circle.—Fig. 23.

23.



Draw line A B through centre of circle; take any radius, as A *e*, and describe the arcs A *e e*, B *e e*; connect *e e*, continuing line to C and D; join A C, A D, etc. (Fig. 23.)

To Describe a Square about a Circle.—Fig. 24.

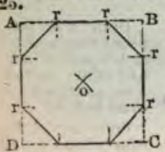
24.

Draw line A B through centre of circle. Take any radius, as A *e*; describe arcs A *e e*, B *e e*; connect *e e*, continuing line to C D.

Describe B *r* and D *r*; draw and extend B *r* and D *r*, and sides A and C parallel to them. (Fig. 24.)

To Describe an Octagon in a Square.—Fig. 25.

25.

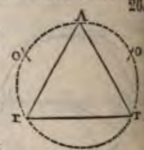


Let A B C D be given square.

Describe A *o r r*, B *o r r*, etc.; join intersections *r r r r*, etc., and figure formed is octagon required. (Fig. 25.)

To Inscribe an Equilateral Triangle in a Circle.—Fig. 26.

26.



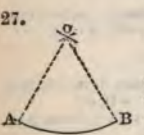
From point A, with A *o* equal to radius of circle, describe *o o*; from *o* and *o* describe *o r*, *o r*; join A *r*, *r r*, and *r* A. (Fig. 26.)

NOTE.—All figures of 10 or 20 sides are readily determined from side of a pentagon, being halved or quartered; and in like manner, all figures of 6, 12, or 24 sides are readily determined from radius of a circle, being equal to the side of a hexagon.

Circles.

To Describe an Arc of a Circle, through Two given Points, with a given Radius.—Fig. 27.

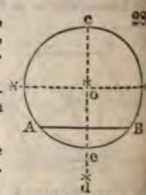
27.



On A B as centres, with given radius, describe arcs cutting at *o*, and from *o* with same radius describe arc A B. (Fig. 27.)

To Ascertain Centre of a Circle or of an Arc of a Circle.—Fig. 28.

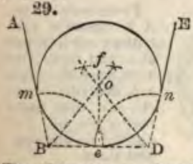
28.



Draw chord A B, bisect it with perpendicular *c d*, then bisect *c d* for centre *o*. (Fig. 28.)

To Describe a Circular Segment that will both fill the angle between two diverging lines and touch them.—Fig. 29.

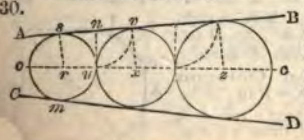
29.



Bisect inclined lines, A B, D E, by line *e f*, and connect perpendicular thereto, B D, to define boundary of segment to be described. Bisect angles at B and D by lines cutting at *o*, and from *o*, with radius *o e*, describe arc *m e n*.

To Draw a Series of Circles between Two Inclined Lines, touching them and each other.—Fig. 30.

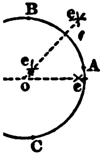
30.



Bisect given lines A B, C D, by line *o o*. From a point *r* in this line erect *r s* perpendicular to A B, and on *r* describe circle *s m*, cutting centre line at *u*; from *u* erect *u n* perpendicular to centre line, cutting A B at *n*, and from *n* describe an arc *n u v*, cutting A B at *v*, erect *x v* parallel to *r s*, making *x* centre of next circle to be described, with radius *x u*, and so on.

t.—*Largest circle* may be described first.

Describe a Circle that shall pass through any three given Points, as A B C.—Figs. 31 and 32.

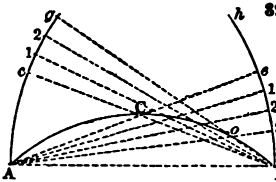


Upon points A and B, with any opening of a dividers, describe arcs cutting each other at *e e*.

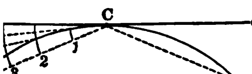
On points B C describe two more cutting each other in points *c c*.

Draw lines *e e* and *c c*, and intersection of these lines, *o*, is centre of circle A B C. (Fig. 31.)

32.



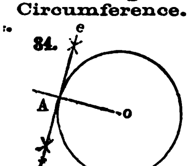
n Centre is not attainable. — From A B as centres, describe arcs A *g*, B *h*; h C draw A *e*, B *c*. Divide A *e* and B *c* into any number of equal parts, also d B *h* into a like number. Draw A 1, 2, 3, etc., and B 1, 2, etc., and intersec- these lines as at *o* are points in the circle required. (Fig. 32.)



Or, let A B C be given points, connect A B, A C, C B, and draw *e c* parallel to A B. Divide C A into a number of equal parts, as at 1, 2, and 3, and from C describe arcs through these points to meet right lines from C to points 1, 2, and 3. on A *e*, and these are points in a circle, to be drawn as directed. (Fig. 33.)

Draw a Tangent to a rcle from a given Point Circumference.—Fig.

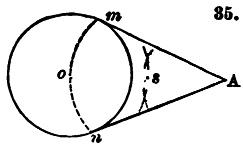
34.



ugh point A draw radial line A *o*, ect perpendicular *e f*. (Fig. 34.)

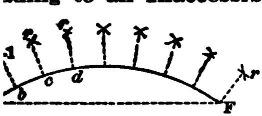
To Draw Tangents to a Circle from a Point without it.—Fig. 35.

35.



From A draw A *o*, and bisect it at *s*; describe arc through *o*, cutting circle at *m n*; join A *m* or A *n*.

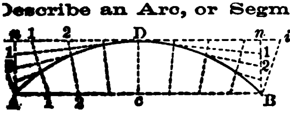
Draw from or to Circumference of a Circle, Lines ading to an Inaccessible Centre.—Fig. 36.



Divide whole or any given portion of circumference into desired number of parts; then, with any radius less than distance of two divisions, describe arcs cutting each other, as A *r*, *b r*, *c r*, *d r*, etc.; draw lines *b r*, *c r*, etc., and they will lead to centre.

raw end lines, as A *r*, F *r*. From *b* describe arc *o*, and with radius *b* 1, from as centres, cut arcs A *r*, etc., and lines A *r*, F *r*, will lead to centre.

Describe an Arc, or Segment of a Circle, of a large Radius.—Fig. 37.

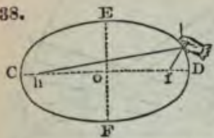


Draw chord A *c* B; also line *h* D *i* parallel with ... d at a distance equal to he ... ment; bisect chord in *c* ... rpendicular *c* D; join A ... h and B i ... icular to A D, B D; erect also perpendiculars A *n* ... h i ... mber of equal parts; draw lines 1 1, 2 2, etc., ... B *n*, ... number of equal parts in A B; draw lines t. ... and at points of intersection with former line.

Ellipse.

To Describe an Ellipse to any Length and Br given.—Fig. 38.

38.

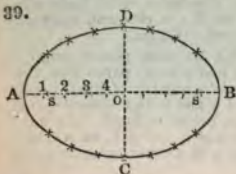


Let longest diameter be C D, and shortest E distance C *o* or *o* D, and with it, from points F describe arcs *h* and *f* upon diameter C D.

Insert pins at *h* and at *f*, and loop a string them of such a length that when a pencil is int within it it will just reach to E or F. Be string, sweep it around centre *o*, and it will ellipse.

NOTE.—It is a property of Ellipse that sum of two lines drawn from *foci* to meet in any curve is equal to transverse diameter.

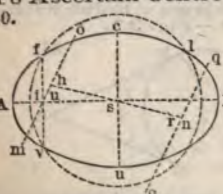
39.



Bisect transverse axis A B at *o*, and on erect perpendicular C D, making *o* D and equal to half conjugate axis. From C or radius A *o*, cut transverse axis at *s s* for *foci* A *o* into any number of equal parts, as 1, With radii A 1, B 1, on *s* and *s* as centres, arcs, and repeat this operation for all oth ions 1, 2, 3, etc., and these points of intersec give line of curve.

To Ascertain Centre and Two Diameters of an El —Fig. 40.

40.



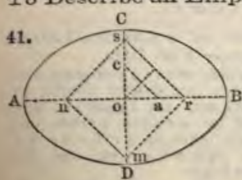
Let A B *c u* be diameters of an Ellipse.

Draw at pleasure two lines, *q q*, *o m*, pa each other, and equidistant from A and B them in points *h n*, and draw line *u r*; in *s*, and upon *s*, as a centre, describe a pleasure, as *f l v*, cutting figure in points *f*

Draw right line *f v*; bisect it in *i*, and points *i s* draw greatest diameter A B, and centre, *s*, draw least diameter *c u*, parallel

To Describe an Ellipse approximately by Circular —Fig. 41.

41.

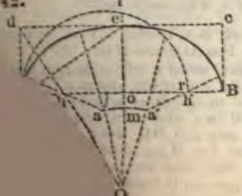


Set off differences of axes from centre *o* *c* on *o* A and *o* C; draw *a c* and bisect it, an its half to *r*; draw *r s* parallel to *a c*, se equal to *o r*, connect *n s*, and draw parall *n m*; from *m*, with radii *m s* and *s m*, desc through C and D, and from *n* and *r* desc through A and B.

NOTE.—This method is not satisfactory w jugate axis is less than two thirds of transve

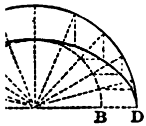
With Arcs of Three Radii. 42.

42.



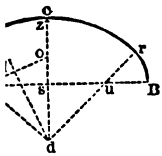
On transverse axis A B draw rectangle on height *o e*; to diagonal A *e* draw perpe *d h* O; set off *o r* equal to *o e*, describe a se on A *r*, and produce O *e* to *l*; set off *o m* *e l*, and on *o* describe an arc with radius A, with radius *o l*, cut this arc at *a*. Thus centres, O, *a*, *a'*, *h*, *h'*, are found, from wh are described to form ellipse.

NOTE.—This process answers for nearly portions of ellipses. It is used in strikin stone bridges, etc.



To Construct an Ellipse from Two Circles.—Fig. 43.

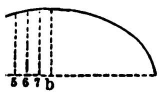
Describe two semicircles, as A B, C D, diameters of which are respectively lengths of major and minor axes. The intersection of the horizontal and vertical lines drawn from any radial line will give a point in the curve C D.



To Construct an Ellipse, when Two Diameters are Given.—Fig. 44.

Make *c o* and A *v* equal to each other, but less than half breadth. Draw *v o*, and from its centre *i* draw and extend perpendicular at *i* to *d*, draw *d v m*, make B *u* = A *v*, draw *d u r*, from *u* and *v* describe B *r* and A *m*, from *d* describe *m c r*, extend *c z* to *s*, and it will be centre for other half of figure.

Construct an Ellipse by Ordinates.—Fig. 45.

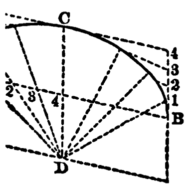


Divide semi-transverse axis, as A *b*, into 8 or 10 divisions, as may be convenient, and erect ordinates, the lengths of which are equal to semi-conjugate, multiplied by the units for each division as follows:

Divisions.

Eighths.		*Tenths.*		
4 12	5 — .927 03	1 — .435 385	5 — .866 02	9 — .994 99
1 44	6 — .968 24	2 — .6	6 — .916 51	10 — 1
063	7 — .992 16	3 — .714 14	7 — .953 94	
603	8 — 1	4 — .8	8 — .979 79	

nstruct an Ellipse when Diameters do not Intersect at Right Angles.—Fig. 46.



Let A B and C D be given diameters.

Draw boundary lines parallel to diameters, divide longest diameter into any number of equal parts, and divide shortest boundary lines into same number of equal parts.

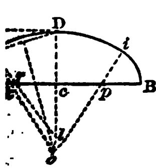
From one end of shortest diameter, D, draw radial lines *through* divisions of longest diameter, and from opposite end, C, draw radial lines to divisions on shortest boundary lines; the intersection of these lines will give points in the curve.

Arcs.

To Describe a Gothic Arc.—Fig. 47.

Take line A B. At points A and B draw arcs B *a* and A *c*, and it will describe arc required.

scribe an Elliptic Arc, Chord and Height being given.—Fig. 48.



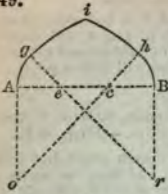
Bisect A B at *c*; erect perpendicular A *q*, and draw line *q* D equal and parallel to A *c*.

Bisect A *c* and A *q* in ... make *c l* equal to *c* D, and draw line *l r* ... *n s* D; bisect *s* D with a line at r... cutting line *c* D at *o*; draw line *o* ... to *c k*, and draw line *o p i*.

Then, from o as a cen... scribe *arc s D i*; and from *k* ... *A k*, describe arcs A *s* a...

To Describe a Gothic Arc.—Figs. 49 and 50.

49.



Divide line A B into three equal parts, $e\ c$; from points A and B let fall perpendiculars A o and B r, equal in length to two of divisions of line A B; draw lines $o\ h$ and $r\ g$ from points e, c; with length of c B, describe arcs A g and B h, and from points o and r describe arcs $g\ i$ and $i\ h$. (Fig. 49.)

50.

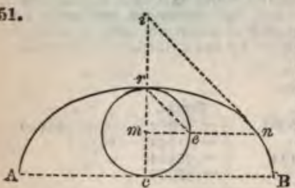
Or, divide line A B into three equal parts at a and b, and on points A, a, b, and B, with distance of two divisions, make four arcs intersecting at c and o.

Through points c, o, and divisions a, b, draw lines $c\ f$ and $o\ e$, on points a and b describe arcs A e and B f, and on points $c\ o$ arcs $f\ s$ and $e\ s$. (Fig. 50.)

Cycloid and Epicycloid.

To Describe a Cycloid.—Fig. 51.

51.



When a circle, as a wheel, rolls over a straight right line, beginning as at A and ending at B, it completes one revolution, and measures a straight line, A B, exactly equal to circumference of circle $c\ e\ r$, which is termed the *generating circle*, and a point or pencil fixed at point r in circumference traces out a curvilinear path, A r B, termed a *cycloid*. A B is its *base* and $c\ r$ its *axis*.

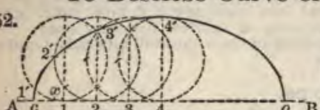
Place generating circle in middle of Cycloid, as in figure; draw a line, $m\ n$, parallel to base, cutting circle at e; and tangent $n\ i$ to curve at point n. The following are some of properties of Cycloid:

Horizontal line $e\ n$ = arc of circle $e\ r$.
Half-base A c = half-circumference $c\ e\ r$.
Arc of Cycloid $r\ n$ = twice chord $r\ e$.
Half-arc of cycloid Ar = twice diameter of circle $r\ c$.

Or, whole arc of Cycloid A r B = four times axis $c\ r$.
Area of Cycloid A r B A = three times area of generating circle $r\ c$.
Tangent $n\ i$ is parallel to chord $e\ r$.

To Describe Curve of a Cycloid.—Fig. 52.

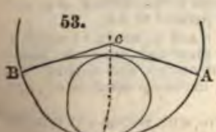
52.



On an indefinite line, A B, set off $c\ o$ = circumference of generating circle, divide this line into any number of equal parts (8 in figure), and at points of division erect perpendiculars thereto. Upon each of these lines describe a circle = generating circle. On c 1 take 1 x = .25 c 1, and with x as a centre, with radius $x\ c$ = .75 c 1, describe an arc cutting circle at 1′; from 2 on next circle, with two distances of 1 1′, measured as chords, cut circle at 2′; from 3 on next circle, with three distances of 1 1′, cut circle at 3′, and proceed in like manner from each side until figure is complete.

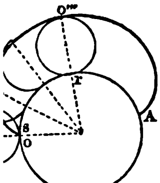
To Describe an Interior Epicycloid or Hypocycloid.—Fig. 53.

53.



If generating circle is rolled on inside of fundamental circle,* as in Fig. 53, it forms an *interior epicycloid*, or *hypocycloid*, A c B, which becomes in this case nearly a straight line. Other points of reference in figure correspond to those in Fig. 51. When diameter of generating circle is equal to half that of fundamental circle, epicycloid becomes a straight line, being diameter of the larger circle.

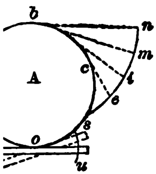
* explanation, Fig. 54.



To Describe an Exterior Epicycloid.—Fig. 54.

An Epicycloid differs from a Cycloid in this, that it is generated by a point, *o'''*, in one circle, *o r*, rolling upon circumference of another, A *r s*, instead of upon a right line or horizontal surface, former being *generating circle* and latter *fundamental circle*.

Generating circle is shown in four positions, in which its generating point is indicated by *o o' o'' o'''*. A *o''' s* is an Epicycloid.



Involute.

To Describe an Involute.—Fig. 55.

Assume A as centre of a circle, *b c o*; a cord laid partly upon its circumference, as *b e*; then the curve *e i m n*, described by a tracer at end of cord, when unwound from a circle, is an involute.

This curve can also be defined by a batten, *x*, rolling on a circle, as *s u*.

Parabola.

To Construct a Parabola by Ordinates or Abscissa.—Figs. 56 and 57.

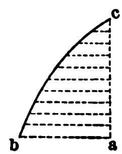
By Ordinates.

Divide ordinate *a b* into 10 equal parts, and erect perpendiculars, length of which will be determined by multiplying abscissa *a c* by respective units for each perpendicular, as follows:

Divisions.

1—.19	3—.51	5—.75	7—.91	9—.99
2—.36	4—.64	6—.84	8—.96	10—1

57.



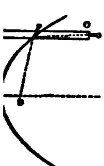
By Abscissa.

ide abcissa *a c* into 8 or 10 equal parts, as may be convenient, raw ordinates thereto, the lengths of which will be deter- l by multiplying half ordinate *a b* by respective units for ordinate, as follows:

Divisions.

Eighths.		*Tenths.*	
—.3535	5—.79057	1—.31623	6—.7746
—.5	6—.86602	2—.44721	7—.83666
—.61237	7—.93541	3—.54772	8—.89443
—.70711	8—1	4—.63245	9—.94868
		5—.70711	10—1

58.

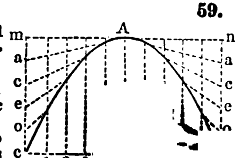


With a Square and Cord.—Fig. 58.

Place a straight edge to directrix A B, and apply to it a square, *c o*.

Attach to end *o* end of a cord equal to *o* A, and attach other end to focus *e*; slide square along straight edge, maintaining cord taut against edge of square, by a point or pencil, and curve will be traced. (Fig. 58.)

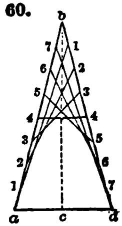
59.



When Height and Base are given.—Fig. 59.

me A B axis and *c d* a double ordinate or base. ugh A draw *m n* parallel to *c d*, and through *c* draw *c m*, *d n*, parallel to axis A B. Divide *c m*, any number of equal parts, as at *a c e o*, also into a like number of parts. Through points and 4 draw lines parallel *to axis*, and through lines *to vertex A, cutting* these perpendiculars, and be traced. *(Fig. 59.)*

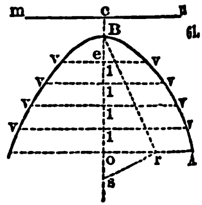
60.



To Describe Curve of a Parabola, Base and Height being given.—Fig. 60.

Draw an isosceles triangle, as *a b d*, base of which shall be equal to, and its height, *c b*, twice that of proposed parabola. Divide each side, *a b*, *d b*, into any number of equal parts; then draw lines, 1 1, 2 2, 3 3, etc., and their intersection will define curve. (Fig. 60.)

To Describe a Parabola, any Ordinate to Axis and its Abscissa being given.—Fig. 61.



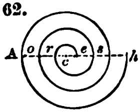
Bisect ordinate, as A *o* in *r*; join B *r*, and draw *r s* perpendicular to it, meeting axis continued to *s*. Set off B *c*, B *e*, each equal to *o s*; draw *m c u* perpendicular to B *s*, then *m u* is directrix and B *e* focus; through *e* and any number of points, 1, 1, 1, etc., in axis, draw double ordinates *v* 1 *v*, and on centre *e*, with radii *e c*, 1 *c*, etc., cut respective ordinates at *v v*, etc., and trace curve through these points.

NOTE.—Line *v e v* passing through focus is parameter.

Spiral.

To Draw a Spiral about a given Point.—Fig. 62.

62.

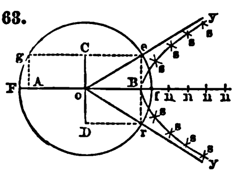


Assume *c* the centre. Draw A *h*, divide it into twice number of parts that there are to be revolutions of line. Upon *c* describe *r e*, *o s*, A *h*, and upon *e* describe *r s*, *o s*, etc.

Hyperbola.

To Describe a Hyperbola, Transverse and Conjugate Diameters being given.—Fig. 63.

63.



Let A B represent transverse diameter, and C D conjugate.

Draw C *e* parallel to A B, and *e r* parallel to C D; draw *o e*, and with radius *o e*, with *o* as a centre, describe circle F *e r*, cutting transverse axis produced in F and *f*; then will F and *f* be foci of figure.

In *o* B produced take any number of points, *n*, *n*, etc., and from F and *f* as centres, with A *n* and B *n* as radii, describe arcs cutting each other in *s*, *s*, etc. Through *s*, *s*, etc., draw curve *s s s s* B *s s s s*.

NOTE.—If straight lines, as *o e y* and *o r y*, are drawn from centre *o* through extremities *e r*, they will be asymptotes of hyperbola, property of which is to approach continually to curve, and yet never to touch it.

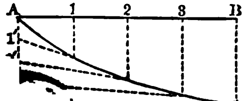
When Foci and Conjugate Axis are given.—Let F and *f* be foci, and C D conjugate axis, as in preceding figure.

Through C draw *g* C *e* parallel to F and *f*; then, with *o* as a centre and *o* F as a radius, describe an arc cutting *g* C *e* at *g* and *e*; from these points let fall perpendiculars upon line connecting F and *f*, and part intercepted between them, as A B, will be transverse axis.

Catenary.

To Delineate a Catenary, Span and Versed Sine being given.—Fig. 64. (*W. Hildenbrand.*)

64.



Divide half span, as A B, into any required number of equal parts, as 1, 2, 3, and let fall B C and A *o*, each equal to versed sine of curve; divide A *o* into like number of parts, 1′, 2′, 3′, as A B. Connect C 1′, C 2′, and C 3′, and points of intersection of perpendiculars let fall from A B will give points through which curve is to be drawn.

Or, suspend a finely linked chain against a ver- trace curve from it on the plane in accordance with conditions of given height, or of given width or length of arc.

r other methods see D. R. Clark's Manual, pp. 18, 19.

Areas of Circles, from $\frac{1}{64}$ to 150.

Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
.000 192	3	7.0686	7	38.4846	14	153.938
.000 767	1/16	7.3662	1/8	39.8713	1/8	156.7
.003 068	1/8	7.6699	1/4	41.2826	1/4	159.485
.012 272	3/16	7.9798	3/8	42.7184	3/8	162.296
.027 612	1/4	8.2958	1/2	44.1787	1/2	165.13
.049 087	5/16	8.618	5/8	45.6636	5/8	167.99
.076 699	3/8	8.9462	3/4	47.1731	3/4	170.874
.110 447	7/16	9.2807	7/8	48.7071	7/8	173.782
.150 33	1/2	9.6211	8	50.2656	15	176.715
.196 35	9/16	9.968	1/8	51.8487	1/8	179.673
.248 505	5/8	10.3206	1/4	53.4563	1/4	182.655
.306 796	11/16	10.679	3/8	55.0884	3/8	185.661
.371 224	3/4	11.0447	1/2	56.7451	1/2	188.692
.441 787	13/16	11.416	5/8	58.4264	5/8	191.748
.518 487	7/8	11.7933	3/4	60.1322	3/4	194.828
.601 322	15/16	12.177	7/8	61.8625	7/8	197.933
.690 292	4	12.5664	9	63.6174	16	201.062
.7854	1/16	12.962	1/8	65.3968	1/8	204.216
.8866	1/8	13.3641	1/4	67.2008	1/4	207.395
.99402	3/16	13.772	3/8	69.0293	3/8	210.598
1.1075	1/4	14.1863	1/2	70.8823	1/2	213.825
1.2272	5/16	14.606	5/8	72.7599	5/8	217.077
1.353	3/8	15.033	3/4	74.6621	3/4	220.354
1.4849	7/16	15.465	7/8	76.5888	7/8	223.655
1.6229	1/2	15.9043	10	78.54	17	226.981
1.7671	9/16	16.349	1/8	80.5158	1/8	230.331
1.9175	5/8	16.8002	1/4	82.5161	1/4	233.706
2.0739	11/16	17.257	3/8	84.5409	3/8	237.105
2.2365	3/4	17.7206	1/2	86.5903	1/2	240.529
2.4053	13/16	18.19	5/8	88.6643	5/8	243.977
2.58	7/8	18.6655	3/4	90.7628	3/4	247.45
2.7612	15/16	19.147	7/8	92.8858	7/8	250.948
2.9483	5	19.635	11	95.0334	18	254.47
3.1416	1/16	20.129	1/8	97.2055	1/8	258.016
3.338	1/8	20.629	1/4	99.4022	1/4	261.587
3.5466	3/16	21.135	3/8	101.6234	3/8	265.183
3.7584	1/4	21.6476	1/2	103.8691	1/2	268.803
3.9761	5/16	22.166	5/8	106.1394	5/8	272.448
4.2	3/8	22.6907	3/4	108.4343	3/4	276.117
4.4301	7/16	23.221	7/8	110.7537	7/8	279.811
4.6664	1/2	23.7583	12	113.098	19	283.529
4.9087	9/16	24.301	1/8	115.466	1/8	287.272
5.1573	5/8	24.8505	1/4	117.859	1/4	291.04
5.4119	11/16	25.406	3/8	120.277	3/8	294.832
5.6723	3/4	25.9673	1/2	122.719	1/2	298.648
5.9396	13/16	26.535	5/8	125.185	5/8	302.489
6.2126	7/8	27.1086	3/4	127.677	3/4	306.355
6.4918	15/16	27.688	7/8	130.192	7/8	310.245
6.7772	6	28.2744	13	132.733	20	314.16
	1/8	29.4648	1/8	135.297	1/8	318.099
	1/4	30.6797	1/4	137.887	1/4	322.063
	3/8	31.9191	3/8	140.501	3/8	326.051
	1/2	33.1831	1/2	143.139	1/2	330.064
	5/8	34.4717	5/8	145.802	5/8	
	3/4	35.7848	3/4	148.49	3/4	
	7/8	37.1224	7/8	151.202	7/8	

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
21	346.361	28	615.754	35	962.115	42	1385.45
1/8	350.497	1/8	621.264	1/8	969	1/8	1393.7
1/4	354.657	1/4	626.798	1/4	975.909	1/4	1401.99
3/8	358.842	3/8	632.357	3/8	982.842	3/8	1410.3
1/2	363.051	1/2	637.941	1/2	989.8	1/2	1418.63
5/8	367.285	5/8	643.549	5/8	996.783	5/8	1426.99
3/4	371.543	3/4	649.182	3/4	1003.79	3/4	1435.37
7/8	375.826	7/8	654.84	7/8	1010.822	7/8	1443.77
22	380.134	29	660.521	36	1017.878	43	1452.2
1/8	384.466	1/8	666.228	1/8	1024.96	1/8	1460.66
1/4	388.822	1/4	671.959	1/4	1032.065	1/4	1469.14
3/8	393.203	3/8	677.714	3/8	1039.195	3/8	1477.64
1/2	397.609	1/2	683.494	1/2	1046.349	1/2	1486.17
5/8	402.038	5/8	689.299	5/8	1053.528	5/8	1494.73
3/4	406.494	3/4	695.128	3/4	1060.732	3/4	1503.3
7/8	410.973	7/8	700.982	7/8	1067.96	7/8	1511.91
23	415.477	30	706.86	37	1075.213	44	1520.53
1/8	420.004	1/8	712.763	1/8	1082.49	1/8	1529.19
1/4	424.558	1/4	718.69	1/4	1089.792	1/4	1537.86
3/8	429.135	3/8	724.642	3/8	1097.118	3/8	1546.56
1/2	433.737	1/2	730.618	1/2	1104.469	1/2	1555.29
5/8	438.364	5/8	736.619	5/8	1111.844	5/8	1564.04
3/4	443.015	3/4	742.645	3/4	1119.244	3/4	1572.81
7/8	447.69	7/8	748.695	7/8	1126.669	7/8	1581.61
24	452.39	31	754.769	38	1134.118	45	1590.43
1/8	457.115	1/8	760.869	1/8	1141.591	1/8	1599.28
1/4	461.864	1/4	766.992	1/4	1149.089	1/4	1608.16
3/8	466.638	3/8	773.14	3/8	1156.612	3/8	1617.05
1/2	471.436	1/2	779.313	1/2	1164.159	1/2	1625.97
5/8	476.259	5/8	785.51	5/8	1171.731	5/8	1634.92
3/4	481.107	3/4	791.732	3/4	1179.327	3/4	1643.89
7/8	485.979	7/8	797.979	7/8	1186.948	7/8	1652.89
25	490.875	32	804.25	39	1194.593	46	1661.91
1/8	495.796	1/8	810.545	1/8	1202.263	1/8	1670.95
1/4	500.742	1/4	816.865	1/4	1209.958	1/4	1680.02
3/8	505.712	3/8	823.21	3/8	1217.677	3/8	1689.11
1/2	510.706	1/2	829.579	1/2	1225.42	1/2	1698.23
5/8	515.726	5/8	835.972	5/8	1233.188	5/8	1707.37
3/4	520.769	3/4	842.391	3/4	1240.981	3/4	1716.54
7/8	525.838	7/8	848.833	7/8	1248.798	7/8	1725.73
26	530.93	33	855.301	40	1256.64	47	1734.95
1/8	536.048	1/8	861.792	1/8	1264.506	1/8	1744.19
1/4	541.19	1/4	868.309	1/4	1272.397	1/4	1753.45
3/8	546.356	3/8	874.85	3/8	1280.312	3/8	1762.74
1/2	551.547	1/2	881.415	1/2	1288.252	1/2	1772.06
	556.763	5/8	888.005	5/8	1296.217	5/8	1781.4
	562.003	3/4	894.62	3/4	1304.206	3/4	1790.76
	567.267	7/8	901.259	7/8	1312.219	7/8	1800.15
	72.557	34	907.922	41	1320.257	48	1809.56
	77.87	1/8	914.611	1/8	1328.32	1/8	1819
	.209	1/4	921.323	1/4	1336.407	1/4	1828.46
	.571	3/8	928.061	3/8	1344.519	3/8	1837.95
	.959	1/2	934.822	1/2	1352.655	1/2	1847.46
	.371	5/8	941.609	5/8	1360.816	5/8	1856.99
	.807	3/4	948.42	3/4	1369.001	3/4	1866.55
	.268	7/8	955.255	7/8	1377.211	7/8	1876.14

…M.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
	1885.75	56	2463.01	63	3117.25	70	3848.46
⅛	1895.38	⅛	2474.02	⅛	3129.64	⅛	3862.22
¼	1905.04	¼	2485.05	¼	3142.04	¼	3876
⅜	1914.72	⅜	2496.11	⅜	3154.47	⅜	3889.8
½	1924.43	½	2507.19	½	3166.93	½	3903.63
⅝	1934.16	⅝	2518.3	⅝	3179.41	⅝	3917.49
¾	1943.91	¾	2529.43	¾	3191.91	¾	3931.37
⅞	1953.69	⅞	2540.58	⅞	3204.44	⅞	3945.27
	1963.5	57	2551.76	64	3217	71	3959.2
⅛	1973.33	⅛	2562.97	⅛	3229.58	⅛	3973.15
¼	1983.18	¼	2574.2	¼	3242.18	¼	3987.13
⅜	1993.06	⅜	2585.45	⅜	3254.81	⅜	4001.13
½	2002.97	½	2596.73	½	3267.46	½	4015.16
⅝	2012.89	⅝	2608.03	⅝	3280.14	⅝	4029.21
¾	2022.85	¾	2619.36	¾	3292.84	¾	4043.29
⅞	2032.82	⅞	2630.71	⅞	3305.56	⅞	4057.39
	2042.83	58	2642.09	65	3318.31	72	4071.51
⅛	2052.85	⅛	2653.49	⅛	3331.09	⅛	4085.66
¼	2062.9	¼	2664.91	¼	3343.89	¼	4099.84
⅜	2072.98	⅜	2676.36	⅜	3356.71	⅜	4114.04
½	2083.08	½	2687.84	½	3369.56	½	4128.26
⅝	2093.2	⅝	2699.33	⅝	3382.44	⅝	4142.51
¾	2103.35	¾	2710.86	¾	3395.33	¾	4156.78
⅞	2113.52	⅞	2722.41	⅞	3408.26	⅞	4171.08
	2123.72	59	2733.98	66	3421.2	73	4185.4
	2133.94	⅛	2745.57	⅛	3434.17	⅛	4199.74
	2144.19	¼	2757.2	¼	3447.17	¼	4214.11
	2154.46	⅜	2768.84	⅜	3460.19	⅜	4228.51
	2164.76	½	2780.51	½	3473.24	½	4242.93
	2175.08	⅝	2792.21	⅝	3486.3	⅝	4257.37
	2185.42	¾	2803.93	¾	3499.4	¾	4271.84
	2195.79	⅞	2815.67	⅞	3512.52	⅞	4286.33
	2206.19	60	2827.44	67	3525.66	74	4300.85
	2216.61	⅛	2839.23	⅛	3538.83	⅛	4315.39
	2227.05	¼	2851.05	¼	3552.02	¼	4329.96
	2237.52	⅜	2862.89	⅜	3565.24	⅜	4344.55
	2248.01	½	2874.76	½	3578.48	½	4359.17
	2258.53	⅝	2886.65	⅝	3591.74	⅝	4373.81
	2269.07	¾	2898.57	¾	3605.04	¾	4388.47
	2279.64	⅞	2910.51	⅞	3618.35	⅞	4403.16
	2290.23	61	2922.47	68	3631.69	75	4417.87
	2300.84	⅛	2934.46	⅛	3645.05	⅛	4432.61
	2311.48	¼	2946.48	¼	3658.44	¼	4447.38
	2322.15	⅜	2958.52	⅜	3671.86	⅜	4462.16
	2332.83	½	2970.58	½	3685.29	½	4476.98
	2343.55	⅝	2982.67	⅝	3698.76	⅝	4491.81
	2354.29	¾	2994.78	¾	3712.24	¾	4506.67
	2365.05	⅞	3006.92	⅞	3725.75	⅞	4521.56
	2375.83	62	3019.08	69	3739.29	76	4536.47
	2386.65	⅛	3031.26	⅛	3752.85	⅛	4551.41
	2397.48	¼	3043.47	¼	3766.43	¼	4566.36
	2408.34	⅜	3055.71	⅜	3780.04	⅜	[illegible]
	2419.23	½	3067.97	½	3793.68	½	[illegible]
	2430.14	⅝	3080.25	⅝	3807.34	⅝	
	2441.07	¾	3092.56	¾	3821.02	¾	
	2452.03	⅞	3104.89	⅞	3834.73	⅞	

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
77	4656.64	84	5541.78	91	6503.9	98	7542.98
1/8	4671.77	1/8	5558.29	1/8	6521.78	1/8	7562.24
1/4	4686.92	1/4	5574.82	1/4	6539.68	1/4	7581.52
3/8	4702.1	3/8	5591.37	3/8	6557.61	3/8	7600.82
1/2	4717.31	1/2	5607.95	1/2	6575.56	1/2	7620.15
5/8	4732.54	5/8	5624.56	5/8	6593.54	5/8	7639.5
3/4	4747.79	3/4	5641.18	3/4	6611.55	3/4	7658.88
7/8	4763.07	7/8	5657.84	7/8	6629.57	7/8	7678.28
78	4778.37	85	5674.51	92	6647.63	99	7697.71
1/8	4793.7	1/8	5691.22	1/8	6665.7	1/8	7717.16
1/4	4809.05	1/4	5707.94	1/4	6683.8	1/4	7736.63
3/8	4824.43	3/8	5724.69	3/8	6701.93	3/8	7756.13
1/2	4839.83	1/2	5741.47	1/2	6720.08	1/2	7775.66
5/8	4855.26	5/8	5758.27	5/8	6738.25	5/8	7795.21
3/4	4870.71	3/4	5775.1	3/4	6756.45	3/4	7814.78
7/8	4886.18	7/8	5791.94	7/8	6774.68	7/8	7834.38
79	4901.68	86	5808.82	93	6792.92	100	7854
1/8	4917.21	1/8	5825.72	1/8	6811.2	1/4	7893.32
1/4	4932.75	1/4	5842.64	1/4	6829.49	1/2	7932.74
3/8	4948.33	3/8	5859.59	3/8	6847.82	3/4	7972.25
1/2	4963.92	1/2	5876.56	1/2	6866.16	101	8011.87
5/8	4979.55	5/8	5893.55	5/8	6884.53	1/4	8051.58
3/4	4995.19	3/4	5910.58	3/4	6902.93	1/2	8091.39
7/8	5010.86	7/8	5927.62	7/8	6921.35	3/4	8131.3
80	5026.56	87	5944.69	94	6939.79	102	8171.3
1/8	5042.28	1/8	5961.79	1/8	6958.26	1/4	8211.41
1/4	5058.03	1/4	5978.91	1/4	6976.76	1/2	8251.61
3/8	5073.79	3/8	5996.05	3/8	6995.28	3/4	8291.91
1/2	5089.59	1/2	6013.22	1/2	7013.82	103	8332.31
5/8	5105.41	5/8	6030.41	5/8	7032.39	1/4	8372.81
3/4	5121.25	3/4	6047.63	3/4	7050.98	1/2	8413.4
7/8	5137.12	7/8	6064.87	7/8	7069.59	3/4	8454.09
81	5153.01	88	6082.14	95	7088.23	104	8494.89
1/8	5168.93	1/8	6099.43	1/8	7106.9	1/4	8535.78
1/4	5184.87	1/4	6116.74	1/4	7125.59	1/2	8576.76
3/8	5200.83	3/8	6134.08	3/8	7144.31	3/4	8617.85
1/2	5216.82	1/2	6151.45	1/2	7163.04	105	8659.03
5/8	5232.84	5/8	6168.84	5/8	7181.81	1/4	8700.32
3/4	5248.88	3/4	6186.25	3/4	7200.6	1/2	8741.7
7/8	5264.94	7/8	6203.69	7/8	7219.41	3/4	8783.18
82	5281.03	89	6221.15	96	7238.25	106	8824.75
1/8	5297.14	1/8	6238.64	1/8	7257.11	1/4	8866.43

IM.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
)	9503.34	120	11309.76	130	13273.26	140	15393.84
¼	9546.59	¼	11356.93	¼	13324.36	¼	15448.87
½	9589.93	½	11404.2	½	13375.56	½	15503.99
¾	9633.37	¾	11451.57	¾	13426.85	¾	15559.22
1	9676.91	121	11499.04	131	13478.25	141	15614.54
¼	9720.55	¼	11546.61	¼	13529.74	¼	15669.96
½	9764.29	½	11594.27	½	13581.33	½	15725.48
¾	9808.12	¾	11642.03	¾	13633.02	¾	15781.09
2	9852.06	122	11689.89	132	13684.81	142	15836.81
¼	9896.09	¼	11737.85	¼	13736.69	¼	15892.62
½	9940.22	½	11785.91	½	13788.68	½	15948.53
¾	9984.45	¾	11834.06	¾	13840.76	¾	16004.54
3	10028.77	123	11882.32	133	13892.94	143	16060.64
¼	10073.2	¼	11930.67	¼	13945.22	¼	16116.85
½	10117.72	½	11979.12	½	13997.6	½	16173.15
¾	10162.34	¾	12027.66	¾	14050.07	¾	16229.55
4	10207.06	124	12076.31	134	14102.64	144	16286.05
¼	10251.88	¼	12125.05	¼	14155.31	¼	16342.65
½	10296.79	½	12173.9	½	14208.08	½	16399.35
¾	10341.8	¾	12222.84	¾	14253.09	¾	16456.14
5	10386.91	125	12271.87	135	14313.91	145	16513.03
¼	10432.12	¼	12321.01	¼	14366.98	¼	16570.02
½	10477.43	½	12370.25	½	14420.14	½	16627.11
¾	10522.84	¾	12419.58	¾	14473.4	¾	16684.3
6	10568.34	126	12469.01	136	14526.76	146	16741.59
¼	10613.94	¼	12518.54	¼	14580.21	¼	16798.97
½	10659.65	½	12568.17	½	14633.77	½	16856.45
¾	10705.44	¾	12618.09	¾	14687.42	¾	16914.03
7	10751.34	127	12667.72	137	14741.17	147	16971.71
¼	10797.34	¼	12717.64	¼	14795.02	¼	17029.48
½	10843.43	½	12767.66	½	14848.97	½	17087.36
¾	10889.62	¾	12817.78	¾	14903.01	¾	17145.33
8	10935.91	128	12867.99	138	14957.16	148	17203.4
¼	10982.3	¼	12918.31	¼	15011.4	¼	17261.57
½	11028.78	½	12968.72	½	15065.74	½	17319.84
¾	11075.37	¾	13019.23	¾	15120.18	¾	17378.2
9	11122.05	129	13069.84	139	15174.71	149	17436.67
¼	11168.83	¼	13120.55	¼	15229.35	¼	17495.23
½	11215.71	½	13171.35	½	15284.08	½	17553.89
¾	11262.69	¾	13222.26	¾	15338.91	150	17671.5

Compute Area of a Circle greater than any in Table.

ULE.—Divide dimension by two, three, four, etc., if practicable to do so, il it is reduced to a diameter to be found in table.

ake tabular area for this diameter, multiply it by square of divisor, and duct will give area required.

AMPLE.—What is area for a diameter of 1050?

$1050 \div 7 = 150$; *tab. area*, $150 = 17\,671.5$, which $\times\ 7^2 = 865\,903.5$, *area.*

Compute Area of a Circle in Feet and Inches, etc., by preceding Table.

ULE.—*Reduce dimension to inches* or eighths, as the case may be, *area in that term from table for that* number.

Divide this number by 64 (square of 8) if it is in eighths, and quotient will give area in inches, and divide again by 144 (square of 12) if it is in inches, and quotient will give area in feet.

EXAMPLE.—What is area of 1 foot 6.375 ins.?

1 foot 6.375 ins. = 18.375 *ins.* = 147 *eighths.* Area of 147 = 16 971.71, which ÷ 64 = 265.181 25 *ins.;* and by 144 = 1.84 125 *feet.*

To Compute Area of a Circle Composed of an Integer and a Fraction.

RULE.—Double, treble, or quadruple dimension given, until fraction is increased to a whole number, or to one of those in the table, as ⅛, ¼, etc., provided it is practicable to do so.

Take area for this diameter; and if it is double of that for which area is required, take one fourth of it; if treble, take one sixteenth of it, etc.

EXAMPLE.—Required area for a circle of 2.1875 ins.

2.1875 × 2 = 4.375, area for which = 15.0331, which ÷ 4 = 3.758 *ins.*

When Diameter is composed of Integers and Fractions contained in Table.

RULE.—Point off a decimal to a diameter from table, and add twice as many figures or ciphers to the right of the area as there are figures cut off from the diameter.

EXAMPLE 1.—What is area of 9675 feet diameter?

Area of 96.75 = 7351.79; hence, area = 73 517 900 *feet.*

2.—What is area of 24 375 feet diameter?

Area of 2.4375 = 4.6664; hence, area = 466 640 000 *feet.*

To Ascertain Area of a Circle as 300, 3000, etc., not contained in Table.

RULE.—Take area of 3 or 30, and add twice the excess of ciphers to the result.

EXAMPLE.—What is area of a circle 3000 feet in diameter?

Area of 30 = 706.86, hence area of 3000 = 7 068 600 *feet.*

To Compute Area of a Circle by Logarithms.

RULE.—To twice log. of diameter add $\bar{1}.895\,091$ (log. of .7854), and sum is log. of area, for which take number.

EXAMPLE.—What is area of a circle 1200 feet in diameter?

Log. 1200 × 2 + $\bar{1}.895\,091$ = 6.158 362 + $\bar{1}.895\,091$ = 6.053 453, and number for which = 1 130 976 *feet.*

Areas of Birmingham Wire Gauge.

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
No.	Sq. Inch.	No.	Sq. Inch.	No.	Sq. Inch.	No.	Sq. Inch.
1	.070 686	10	.014 103	19	.001 385	28	.000 154
2	.063 347	11	.011 309	20	.000 962	29	.000 133
	.052 685	12	.009 331	21	.000 804	30	.000 113
	.044 488	13	.007 088	22	.000 616	31	.000 078
	.038 013	14	.005 411	23	.000 491	32	.000 064
	.032 365	15	.004 071	24	.000 38	33	.000 05
	.025 447	16	.003 318	25	.000 314	34	.000 038
	.021 382	17	.002 642	26	.000 254	35	.000 02
	.017 203	18	.001 886	27	.000 201	36	.000 013

Circumferences of Circles, from $\frac{1}{64}$ to 150.

Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
.04909	3	9.4248	8	25.1328	15	47.124
.09818	1/16	9.6211	1/8	25.5255	1/8	47.5167
	1/8	9.8175	1/4	25.9182	1/4	47.9094
.19635	3/16	10.014	3/8	26.3109	3/8	48.3021
.3927	1/4	10.2102	1/2	26.7036	1/2	48.6948
	5/16	10.406	5/8	27.0963	5/8	49.0875
.589	3/8	10.6029	3/4	27.489	3/4	49.4802
.7854	7/16	10.799	7/8	27.8817	7/8	49.8729
.98175	1/2	10.9956	9	28.2744	16	50.2656
	9/16	11.191	1/8	28.6671	1/8	50.6583
1.1781	5/8	11.3883	1/4	29.0598	1/4	51.051
1.37445	11/16	11.584	3/8	29.4525	3/8	51.4437
	3/4	11.781	1/2	29.8452	1/2	51.8364
1.5708	13/16	11.977	5/8	30.2379	5/8	52.2291
1.76715	7/8	12.1737	3/4	30.6306	3/4	52.6218
1.9635	15/16	12.369	7/8	31.0233	7/8	53.0145
	4	12.5664	10	31.416	17	53.4072
2.15985	1/16	12.762	1/8	31.8087	1/8	53.7999
2.3562	1/8	12.9591	1/4	32.2014	1/4	54.1926
	3/16	13.155	3/8	32.5941	3/8	54.5853
2.55255	1/4	13.3518	1/2	32.9868	1/2	54.978
2.7489	5/16	13.547	5/8	33.3795	5/8	55.3707
	3/8	13.7445	3/4	33.7722	3/4	55.7634
2.94525	7/16	13.94	7/8	34.1649	7/8	56.1561
3.1416	1/2	14.1372	11	34.5576	18	56.5488
3.3379	9/16	14.333	1/8	34.9503	1/8	56.9415
3.5343	5/8	14.5299	1/4	35.343	1/4	57.3342
3.7306	11/16	14.725	3/8	35.7357	3/8	57.7269
3.927	3/4	14.9226	1/2	36.1284	1/2	58.1196
4.1233	13/16	15.119	5/8	36.5211	5/8	58.5123
4.3197	7/8	15.3153	3/4	36.9138	3/4	58.905
4.516	15/16	15.511	7/8	37.3065	7/8	59.2977
4.7124	5	15.708	12	37.6992	19	59.6904
4.9087	1/8	16.1007	1/8	38.0919	1/8	60.0831
5.1051	1/4	16.4934	1/4	38.4846	1/4	60.4758
5.3014	3/8	16.8861	3/8	38.8773	3/8	60.8685
5.4978	1/2	17.2788	1/2	39.27	1/2	61.2612
5.6941	5/8	17.6715	5/8	39.6627	5/8	61.6539
5.8905	3/4	18.0642	3/4	40.0554	3/4	62.0466
6.0868	7/8	18.4569	7/8	40.4481	7/8	62.4393
6.2832	6	18.8496	13	40.8408	20	62.832
6.4795	1/8	19.2423	1/8	41.2335	1/8	63.2247
6.6759	1/4	19.635	1/4	41.6262	1/4	63.6174
6.8722	3/8	20.0277	3/8	42.0189	3/8	64.0101
7.0686	1/2	20.4204	1/2	42.4116	1/2	64.4028
7.2649	5/8	20.8131	5/8	42.8043	5/8	64.7955
7.4613	3/4	21.2058	3/4	43.197	3/4	65.1882
7.6576	7/8	21.5985	7/8	43.5897	7/8	65.5809
7.854	7	21.9912	14	43.9824	21	65.9736
8.0503	1/8	22.3839	1/8	44.3751	1/8	66.3663
8.2467	1/4	22.7766	1/4	44.7678	1/4	66.759
8.443	3/8	23.1693	3/8	45.1605	3/8	67.1517
8.6394	1/2	23.562	1/2	45.5532	1/2	67.5444
8.8357	5/8	23.9547	5/8	45.9459	5/8	67.9371
9.0321	3/4	24.3474	3/4	46.3386	3/4	68.3298
9.2284	7/8	24.7401	7/8	46.7313	7/8	68.7225

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	C
22	69.1152	29	91.1064	36	113.098	43	13
1/8	69.5079	1/8	91.4991	1/8	113.49	1/8	13
1/4	69.9006	1/4	91.8918	1/4	113.883	1/4	13
3/8	70.2933	3/8	92.2845	3/8	114.276	3/8	13
1/2	70.686	1/2	92.6772	1/2	114.668	1/2	13
5/8	71.0787	5/8	93.0699	5/8	115.061	5/8	13
3/4	71.4714	3/4	93.4626	3/4	115.454	3/4	13
7/8	71.8641	7/8	93.8553	7/8	115.846	7/8	13
23	72.2568	30	94.248	37	116.239	44	13
1/8	72.6495	1/8	94.6407	1/8	116.632	1/8	13
1/4	73.0422	1/4	95.0334	1/4	117.025	1/4	13
3/8	73.4349	3/8	95.4261	3/8	117.417	3/8	13
1/2	73.8276	1/2	95.8188	1/2	117.81	1/2	13
5/8	74.2203	5/8	96.2115	5/8	118.203	5/8	14
3/4	74.613	3/4	96.6042	3/4	118.595	3/4	14
7/8	75.0057	7/8	96.9969	7/8	118.988	7/8	14
24	75.3984	31	97.3896	38	119.381	45	14
1/8	75.7911	1/8	97.7823	1/8	119 773	1/8	14
1/4	76.1838	1/4	98.175	1/4	120.166	1/4	14
3/8	76.5765	3/8	98.5677	3/8	120.559	3/8	14
1/2	76.9692	1/2	98.9604	1/2	120.952	1/2	14
5/8	77.3619	5/8	99 3531	5/8	121.344	5/8	14
3/4	77.7546	3/4	99.7458	3/4	121.737	3/4	1
7/8	78.1473	7/8	100.1385	7/8	122.13	7/8	1
25	78.54	32	100.5312	39	122.522	46	1
1/8	78.9327	1/8	100.9239	1/8	122.915	1/8	1
1/4	79.3254	1/4	101.3166	1/4	123.308	1/4	1
3/8	79.7181	3/8	101.7093	3/8	123.7	3/8	1
1/2	80.1108	1/2	102.102	1/2	124.093	1/2	1
5/8	80.5035	5/8	102.4947	5/8	124.486	5/8	1
3/4	80.8962	3/4	102.8874	3/4	124.879	3/4	1
7/8	81.2889	7/8	103.2801	7/8	125.271	7/8	1
26	81.6816	33	103.673	40	125.664	47	1
1/8	82.0743	1/8	104.065	1/8	126.057	1/8	1
1/4	82.467	1/4	104.458	1/4	126.449	1/4	1
3/8	82.8597	3/8	104.851	3/8	126.842	3/8	1
1/2	83.2524	1/2	105.244	1/2	127.235	1/2	1
5/8	83.6451	5/8	105.636	5/8	127.627	5/8	1
3/4	84.0378	3/4	106.029	3/4	128.02	3/4	1
7/8	84.4305	7/8	106.422	7/8	128.413	7/8	1
27	84.8232	34	106.814	41	128.806	48	1
1/8	85.2159	1/8	107 207	1/8	129.198	1/8	1
1/4	85.6086	1/4	107.6	1/4	129.591	1/4	1
3/8	86.0013	3/8	107.992	3/8	129.984	3/8	1
1/2	86.394	1/2	108.385	1/2	130.376	1/2	1
5/8	86.7867	5/8	108.778	5/8	130.769	5/8	1
3/4	87.1794	3/4	109.171	3/4	131.162	3/4	1
7/8	87.5721	7/8	109 563	7/8	131.554	7/8	1
28	87.9648	35	109.956	42	131.947	49	1
1/8	88.3575	1/8	110.349	1/8	132.34	1/8	1
1/4	88.7502	1/4	110.741	1/4	132.733	1/4	1
	89.1429	3/8	111.134	3/8	133.125	3/8	1
	89.5356	1/2	111.527	1/2	133.518	1/2	1
	[illegible]0283	5/8	111.919	5/8	133.911	5/8	1
		3/4	112.312	3/4	134.303	3/4	
		7/8	112.705	7/8	134.696	7/8	

Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
157.08	57	179.071	64	201.062	71	223.054
157.473	1/8	179.464	1/8	201.455	1/8	223.446
157.865	1/4	179.857	1/4	201.848	1/4	223.839
158.258	3/8	180.249	3/8	202.24	3/8	224.232
158.651	1/2	180.642	1/2	202.633	1/2	224.624
159.043	5/8	181.035	5/8	203.026	5/8	225.017
159.436	3/4	181.427	3/4	203.419	3/4	225.41
159.829	7/8	181.82	7/8	203.811	7/8	225.802
160.222	58	182.213	65	204.204	72	226.195
160.614	1/8	182.605	1/8	204.597	1/8	226.588
161.007	1/4	182.998	1/4	204.989	1/4	226.981
161.4	3/8	183.391	3/8	205.382	3/8	227.373
161.792	1/2	183.784	1/2	205.775	1/2	227.766
162.185	5/8	184.176	5/8	206.167	5/8	228.159
162.578	3/4	184.569	3/4	206.56	3/4	228.551
162.97	7/8	184.962	7/8	206.953	7/8	228.944
163.363	59	185.354	66	207.346	73	229.337
163.756	1/8	185.747	1/8	207.738	1/8	229.729
164.149	1/4	186.14	1/4	208.131	1/4	230.122
164.541	3/8	186.532	3/8	208.524	3/8	230.515
164.934	1/2	186.925	1/2	208.916	1/2	230.908
165.327	5/8	187.318	5/8	209.309	5/8	231.3
165.719	3/4	187.711	3/4	209.702	3/4	231.693
166.112	7/8	188.103	7/8	210.094	7/8	232.086
166.505	60	188.496	67	210.487	74	232.478
166.897	1/8	188.889	1/8	210.88	1/8	232.871
167.29	1/4	189.281	1/4	211.273	1/4	233.264
167.683	3/8	189.674	3/8	211.665	3/8	233.656
168.076	1/2	190.067	1/2	212.058	1/2	234.049
168.468	5/8	190.459	5/8	212.451	5/8	234.442
168.861	3/4	190.852	3/4	212.843	3/4	234.835
169.254	7/8	191.245	7/8	213.236	7/8	235.227
169.646	61	191.638	68	213.629	75	235.62
170.039	1/8	192.03	1/8	214.021	1/8	236.013
170.432	1/4	192.423	1/4	214.414	1/4	236.405
170.824	3/8	192.816	3/8	214.807	3/8	236.798
171.217	1/2	193.208	1/2	215.2	1/2	237.191
171.61	5/8	193.601	5/8	215.592	5/8	237.583
172.003	3/4	193.994	3/4	215.985	3/4	237.976
172.395	7/8	194.386	7/8	216.378	7/8	238.369
172.788	62	194.779	69	216.77	76	238.762
173.181	1/8	195.172	1/8	217.163	1/8	239.154
173.573	1/4	195.565	1/4	217.556	1/4	239.547
173.966	3/8	195.957	3/8	217.948	3/8	239.94
174.359	1/2	196.35	1/2	218.341	1/2	240.332
174.751	5/8	196.743	5/8	218.734	5/8	240.725
175.144	3/4	197.135	3/4	219.127	3/4	241.118
175.537	7/8	197.528	7/8	219.519	7/8	241.51
175.93	63	197.921	70	219.912	77	[illegible]
176.322	1/8	198.313	1/8	220.305		
176.715	1/4	198.706	1/4	220.697		
177.108	3/8	199.099	3/8	221.09		
177.5	1/2	199.492	1/2	221.483		
177.893	5/8	199.884	5/8	221.875		
178.286	3/4	200.277	3/4	222.268		
178.678	7/8	200.67	7/8	222.661		

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
78	245.045	85	267.036	92	289.027	99	311.018
1/8	245.437	1/8	267.429	1/8	289.42	1/8	311.411
1/4	245.83	1/4	267.821	1/4	289.813	1/4	311.804
3/8	246.223	3/8	268.214	3/8	290.205	3/8	312.196
1/2	246.616	1/2	268.607	1/2	290.598	1/2	312.589
5/8	247.008	5/8	268.999	5/8	290.991	5/8	312.982
3/4	247.401	3/4	269.392	3/4	291.383	3/4	313.375
7/8	247.794	7/8	269.785	7/8	291.776	7/8	313.767
79	248.186	86	270.178	93	292.169	100	314.16
1/8	248.579	1/8	270.57	1/8	292.562	1/4	314.945
1/4	248.972	1/4	270.963	1/4	292.954	1/2	315.731
3/8	249.364	3/8	271.356	3/8	293.347	3/4	316.516
1/2	249.757	1/2	271.748	1/2	293.74	101	317.302
5/8	250.15	5/8	272.141	5/8	294.132	1/4	318.087
3/4	250.543	3/4	272.534	3/4	294.525	1/2	318.872
7/8	250.935	7/8	272.926	7/8	294.918	3/4	319.658
80	251.328	87	273.319	94	295.31	102	320.443
1/8	251.721	1/8	273.712	1/8	295.703	1/4	321.229
1/4	252.113	1/4	274.105	1/4	296.096	1/2	322.014
3/8	252.506	3/8	274.497	3/8	296.488	3/4	322.799
1/2	252.899	1/2	274.89	1/2	296.881	103	323.585
5/8	253.291	5/8	275.283	5/8	297.274	1/4	324.37
3/4	253.684	3/4	275.675	3/4	297.667	1/2	325.156
7/8	254.077	7/8	276.068	7/8	298.059	3/4	325.941
81	254.47	88	276.461	95	298.452	104	326.726
1/8	254.862	1/8	276.853	1/8	298.845	1/4	327.512
1/4	255.255	1/4	277.246	1/4	299.237	1/2	328.297
3/8	255.648	3/8	277.629	3/8	299.63	3/4	329.083
1/2	256.04	1/2	278.032	1/2	300.023	105	329.868
5/8	256.433	5/8	278.424	5/8	300.415	1/4	330.653
3/4	256.826	3/4	278.817	3/4	300.808	1/2	331.439
7/8	257.218	7/8	279.21	7/8	301.201	3/4	332.224
82	257.611	89	279.602	96	301.594	106	333.01
1/8	258.004	1/8	279.995	1/8	301.986	1/4	333.795
1/4	258.397	1/4	280.388	1/4	302.379	1/2	334.58
3/8	258.789	3/8	280.78	3/8	302.772	3/4	335.366
1/2	259.182	1/2	281.173	1/2	303.164	107	336.151
5/8	259.575	5/8	281.566	5/8	303.557	1/4	336.937
3/4	259.967	3/4	281.959	3/4	303.95	1/2	337.722
7/8	260.36	7/8	282.351	7/8	304.342	3/4	338.507
83	260.753	90	282.744	97	304.735	108	339.293
1/8	261.145	1/8	283.137	1/8	305.128	1/4	340.078
1/4	261.538	1/4	283.529	1/4	305.521	1/2	340.864
3/8	261.931	3/8	283.922	3/8	305.913	3/4	341.649
1/2	262.324	1/2	284.315	1/2	306.306	109	342.434
5/8	262.716	5/8	284.707	5/8	306.699	1/4	343.22
3/4	263.109	3/4	285.1	3/4	307.091	1/2	344.005
	263.502	7/8	285.493	7/8	307.484	3/4	344.791
	263.894	91	285.886	98	307.877	110	345.576
	264.287	1/8	286.278	1/8	308.27	1/4	346.361
	264.68	1/4	286.671	1/4	308.662	1/2	347.147
	65.072	3/8	287.064	3/8	309.055	3/4	347.932
	55.465	1/2	287.456	1/2	309.448	111	348.718
	5.858	5/8	287.849	5/8	309.84	1/4	349.503
	5.251	3/4	288.242	3/4	310.233	1/2	350.288
	.643	7/8	288.634	7/8	310.626	3/4	351.074

Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
351.859	121	380.134	130	408.408	139	436.682
352.645	¼	380.919	¼	409.192	¼	437.467
353.43	½	381.704	½	409.979	½	438.253
354.215	¾	382.49	¾	410.763	¾	439.037
355.001	122	383.275	131	411.55	140	439.824
355.786	¼	384.061	¼	412.334	¼	440.608
356.572	½	384.846	½	413.12	½	441.395
357.357	¾	385.631	¾	413.905	¾	442.179
358.142	123	386.417	132	414.691	141	442.966
358.928	¼	387.202	¼	415.476	¼	443.75
359.713	½	387.988	½	416.262	½	444.536
360.499	¾	388.773	¾	417.046	¾	445.321
361.284	124	389.558	133	417.833	142	446.107
362.069	¼	390.344	¼	418.617	¼	446.891
362.855	½	391.129	½	419.404	½	447.678
363.64	¾	391.915	¾	420.188	¾	448.462
364.426	125	392.7	134	420.974	143	449.249
365.211	¼	393.484	¼	421.759	¼	450.033
365.996	½	394.271	½	422.545	½	450.82
366.782	¾	395.055	¾	423.33	¾	451.604
367.567	126	395.842	135	424.116	144	452.39
368.353	¼	396.626	¼	424.9	¼	453 175
369.138	½	397.412	½	425.687	½	453.961
369.923	¾	398.197	¾	426.471	¾	454.745
370.709	127	398.983	136	427.258	145	455.532
371.494	¼	399.768	¼	428.042	¼	456.316
372.28	½	400.554	½	428.828	½	457.103
373.065	¾	401.338	¾	429.613	146	458.674
373.85	128	402.125	137	430.399	½	460.244
374.636	¼	402.909	¼	431.183	147	461.815
375.421	½	403.696	½	431.97	½	463.386
376.207	¾	404.48	¾	432.754	148	464.957
376.992	129	405.266	138	433.541	½	466.528
377.777	¼	406.051	¼	434.325	149	468.098
378.563	½	406.837	½	435.112	½	469.669
379.348	¾	407.622	¾	435.896	150	471.24

npute Circumference of a Diameter greater than any in preceding Table.

–Divide dimension by two, three, four, etc., if practicable to do so, reduced to a diameter in table.
abular circumference for this dimension, multiply it by divisor, as it was divided, and product will give circumference required.

e.—What is circumference for a diameter of 1050?

r = 150; *tab. circum.*, 150 = 471.24, which × 7 = 3298.68, *circumf*

npute Circumference of a Diameter in Fe Inches, etc., by preceding Table.

–Reduce dimension to inches or eighths, as the case may mference in that term from table for that number.
this number by 8 if it is in eighths, and by 12 if in inch *ill give circumference in feet.*

EXAMPLE.—Required circumference of a circle of 1 foot 6.375 ins.

1 foot 6.375 ins. = 18.375 *ins.* = 147 *eighths.* Circum. of 147 = 461.815, which ÷ 8 = 57.727 *ins.;* and by 12 = 4.8106 *feet.*

To Compute Circumference for a Diameter composed of an Integer and a Fraction.

RULE.—Double, treble, or quadruple dimension given, until fraction is increased to a whole number or to one of those in the table, as 1/8, 1/4, etc., provided it is practicable to do so.

Take circumference for this diameter; and if it is double of that for which circumference is required, take one half of it; if treble, take one third of it; and if quadruple, one fourth of it.

EXAMPLE.—Required circumference of 2.21875 ins.

2.21875 × 2 = 4.4375, which × 2 = 8.875; circum. for which = 27.8817, which ÷ 4 = 6.9704 *ins.*

When Diameter consists of Integers and Fractions contained in Table.

RULE.—Point a decimal to a diameter in table, take circumference from table, and add as many figures to the right as there are figures cut off.

EXAMPLE.—What is circumference of a circle 9675 feet in diameter?

Circumference of 96.75 = 303.95; hence, circumference of 9675 = 30395 *feet.*

To Ascertain Circumference for a Diameter, as 500, 5000, etc., not contained in Table.

Rule.—Take circumference of 5 or 50 from table, and add the excess of ciphers to the result.

EXAMPLE.—What is circumference of a circle 8000 feet in diameter?

Circumference of 80 = 251.38; hence, circumference of 8000 = 25138 *feet.*

To Compute Circumference of a Circle by Logarithms.

RULE.—To log. of diameter add .49715 (log. of 3.1416), and sum is log. of circumference, from which take number.

EXAMPLE.—What is circumference of a circle 1200 feet in diameter?

Log. 1200 = 3.07918 + .49715 = 3.57633, and number for which = 3769.92 *feet.*

Circumferences of Birmingham Wire Gauge.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
No.	Ins.	No.	Ins.	No.	Ins.	No.	Ins.
1	.94248	10	.42097	19	.13195	28	.04398
2	.89221	11	.37699	20	.10995	29	.04084
3	.81367	12	.34243	21	.10053	30	.0377
4	.7477	13	.29845	22	.08796	31	.03141
5	.69115	14	.26075	23	.07854	32	.02827
	.63774	15	.22619	24	.06911	33	.02513
	.56549	16	.2042	25	.06283	34	.02199
	36	17	.18221	26	.05655	35	.01571
		18	.15394	27	.05026	36	.01257

Areas and Circumferences. *(Advancing by Tenths.)*

Area.	Circum.	Diam.	Area.	Circum.
.007854	.31416	.6	24.6301	17.593
.031416	.62832	.7	25.5176	17.9071
.070686	.94248	.8	26.4209	18.2213
.125664	1.2566	.9	27.3398	18.5354
.19635	1.5708	6	28.2744	18.8496
.282744	1.885	.1	29.2247	19.1638
.384846	2.1991	.2	30.1908	19.4779
.502656	2.5133	.3	31.1725	19.7921
.636174	2.8274	.4	32.17	20.1062
.7854	3.1416	.5	33.1831	20.4204
.9503	3.4558	.6	34.212	20.7346
1.131	3.7699	.7	35.2566	21.0487
1.3273	4.0841	.8	36.3169	21.3629
1.5394	4.3982	.9	37.3929	21.677
1.7671	4.7124	7	38.4846	21.9912
2.0106	5.0266	.1	39.592	22.3054
2.2698	5.3407	.2	40.7151	22.6195
2.5447	5.6549	.3	41.854	22.9337
2.8353	5.969	.4	43.0085	23.2478
3.1416	6.2832	.5	44.1787	23.562
3.4636	6.5974	.6	45.3647	23.8762
3.8013	6.9115	.7	46.5664	24.1903
4.1548	7.2257	.8	47.7837	24.5045
4.5239	7.5398	.9	49.0168	24.8186
4.9087	7.854	8	50.2656	25.1328
5.3093	8.1682	.1	51.5301	25.447
5.7256	8.4823	.2	52.8103	25.7611
6.1575	8.7965	.3	54.1062	26.0753
6.6052	9.1106	.4	55.4178	26.3894
7.0686	9.4248	.5	56.7451	26.7036
7.5477	9.739	.6	58.0882	27.0178
8.0425	10.0531	.7	59.4469	27.3319
8.553	10.3673	.8	60.8214	27.6461
9.0792	10.6814	.9	62.2115	27.9602
9.6211	10.9956	9	63.6174	28.2744
10.1788	11.3098	.1	65.039	28.5886
10.7521	11.6239	.2	66.4763	28.9027
11.3412	11.9381	.3	67.9292	29.2169
11.9459	12.2522	.4	69.3979	29.531
12.5664	12.5664	.5	70.8823	29.8452
13.2026	12.8806	.6	72.3825	30.1594
13.8545	13.1947	.7	73.8983	30.4735
14.522	13.5089	.8	75.4298	30.7877
15.2053	13.823	.9	76.9771	31.1018
15.9043	14.1372	10	78.54	31[illegible]
16.6191	14.4514	.1	80.1187	[illegible]
17.3495	14.7655	.2	81.713	[illegible]
18.0956	15.0797	.3	83.3231	[illegible]
18.8575	15.3938	.4	84.9489	[illegible]
19.635	15.708	.5	86.5903	[illegible]
20.4283	16.0222	.6	88.2475	[illegible]
21.2372	16.3363	.7	89.9204	[illegible]
22.0619	16.6505	.8	91.6091	[illegible]
22.9023	16.9646	.9	93.3134	[illegible]
23.7583	17.2788			

Diam.	Area.	Circum.
33	855.3006	103.6728
.1	860.4921	103.987
.2	865.6993	104.3011
.3	870.9222	104.6153
.4	876.1608	104.9294
.5	881.4151	105.2436
.6	886.6852	105.5578
.7	891.9709	105.8719
.8	897.2724	106.1861
.9	902.5895	106.5002
34	907.9224	106.8144
.1	913.271	107.1286
.2	918.6353	107.4427
.3	924.0152	107.7569
.4	929.4109	108.071
.5	934.8223	108.3852
.6	940.2495	108.6994
.7	945.6923	109.0135
.8	951.1508	109.3277
.9	956.6251	109.6418
35	962.115	109.956
.1	967.6207	110.2702
.2	973.142	110.5843
.3	978.6791	110.8985
.4	984.2319	111.2126
.5	989.8003	111.5268
.6	995.3845	111.841
.7	1000.9844	112.1551
.8	1006.6001	112.4693
.9	1012.2314	112.7834
36	1017.8784	113.0976
.1	1023.5411	113.4118
.2	1029.2196	113.7259
.3	1034.9137	114.0401
.4	1040.6236	114.3542
.5	1046.3491	114.6684
.6	1052.0904	114.9826
.7	1057.8474	115.2967
.8	1063.6201	115.6109
.9	1069.4085	115.925
37	1075.2126	116.2392
.1	1081.0324	116.5534
.2	1086.8679	116.8675
.3	1092.7192	117.1817
.4	1098.5861	117.4958
.5	1104.4687	117.81
.6	1110.3671	118.1242
.7	1116.2812	118.4383
.8	1122.2109	118.7525
.9	1128.1564	119.0666
[illegible]8	1134.1176	119.3808
	1140.0945	119.695
	1146.0871	120.0091
	1152.0954	120.3233
	[illegible]58.1194	120.6374
.5	1164.1591	120.9516
.6	1170.2146	121.2658
.7	1176.2857	121.5799
.8	1182.3726	121.8941
.9	1188.4751	122.2082
39	1194.5934	122.5224
.1	1200.7274	122.8366
.2	1206.8771	123.1507
.3	1213.0424	123.4649
.4	1219.2235	123.779
.5	1225.4203	124.0932
.6	1231.6329	124.4074
.7	1237.8611	124.7215
.8	1244.105	125.0357
.9	1250.3647	125.3498
40	1256.64	125.664
.1	1262.9311	125.9782
.2	1269.2378	126.2923
.3	1275.5603	126.6065
.4	1281.8985	126.9206
.5	1288.2523	127.2348
.6	1294.6219	127.549
.7	1301.0072	127.8631
.8	1307.4083	128.1773
.9	1313.825	128.4914
41	1320.2574	128.8056
.1	1326.7055	129.1198
.2	1333.1694	129.4339
.3	1339.6489	129.7481
.4	1346.1442	130.0622
.5	1352.6551	130.3764
.6	1359.1818	130.6906
.7	1365.7242	131.0047
.8	1372.2823	131.3189
.9	1378.8561	131.633
42	1385.4456	131.9472
.1	1392.0508	132.2614
.2	1398.6717	132.5755
.3	1405.3084	132.8897
.4	1411.9607	133.2038
.5	1418.6287	133.518
.6	1425.3125	133.8322
.7	1432.012	134.1463
.8	1438.7271	134.4605
.9	1445.458	134.7746
43	1452.2046	135.0888
.1	1458.9669	135.403
.2	1465.7449	135.7171
.3	1472.5386	136.0313
.4	1479.348	136.3454
.5	1486.1731	136.6596
.6	1493.014	136.9738
.7	1499.8705	137.2879
.8	1506.7428	137.6021
.9	1513.6307	137.9162

Diam.	Area.	Circum.	Diam.	Area.	Circum.
	1520.5344	138.2304	.5	1924.4263	155.5092
	1527.4538	138.5446	.6	1932.2097	155.8234
	1534.3889	138.8587	.7	1940.0087	156.1375
	1541.3396	139.1729	.8	1947.8234	156.4517
	1548.3061	139.487	.9	1955.6539	156.7658
	1555.2883	139.8012	50	1963.5	157.08
	1562.2863	140.1154	.1	1971.3619	157.3942
	1569.2999	140.4295	.2	1979.2394	157.7083
	1576.3292	140.7437	.3	1987.1327	158.0225
	1583.3743	141.0578	.4	1995.0417	158.3366
	1590.435	141.372	.5	2002.9663	158.6509
	1597.5115	141.6862	.6	2010.9067	158.965
	1604.6036	142.0003	.7	2018.8628	159.2791
	1611.7115	142.3145	.8	2026.8347	159.5933
	1618.8351	142.6286	.9	2034.8222	159.9074
	1625.9743	142.9428	51	2042.8254	160.2216
	1633.1293	143.257	.1	2050.8443	160.5358
	1640.3	143.5711	.2	2058.879	160.8499
	1647.4865	143.8853	.3	2066.9293	161.1641
	1654.6886	144.1994	.4	2074.9954	161.4782
	1661.9064	144.5136	.5	2083.0771	161.7924
	1669.1399	144.8278	.6	2091.1746	162.1066
	1676.3892	145.1419	.7	2099.2878	162.4207
	1683.6541	145.4561	.8	2107.4167	162.7349
	1690.9348	145.7702	.9	2115.5613	163.049
	1698.2311	146.0844	52	2123.7216	163.3632
	1705.5432	146.3986	.1	2131.8976	163.6774
	1712.871	146.7127	.2	2140.0893	163.9915
	1720.2145	147.0269	.3	2148.2968	164.3057
	1727.5737	147.341	.4	2156.5199	164.6198
	1734.9486	147.6552	.5	2164.7587	164.934
	1742.3392	147.9694	.6	2173.0133	165.2482
	1749.7455	148.2835	.7	2181.2836	165.5623
	1757.1676	148.5977	.8	2189.5695	165.8765
	1764.6053	148.9118	.9	2197.8712	166.1906
	1772.0587	149.226	53	2206.1886	166.5048
	1779.5279	149.5402	.1	2214.5217	166.819
	1787.0128	149.8543	.2	2222.8705	167.1331
	1794.5133	150.1685	.3	2231.235	167.4473
	1802.0296	150.4826	.4	2239.6152	167.7614
	1809.5616	150.7968	.5	2248.0111	168.0756
	1817.1093	151.111	.6	2256.4228	168.3898
	1824.6727	151.4251	.7	2264.8501	168.7039
	1832.2518	151.7393	.8	2273.2932	169.0181
	1839.8466	152.0534	.9	2281.7519	169.3322
	1847.4571	152.3676	54	2290.2264	16
	1855.0834	152.6818	.1	2298.7166	
	1862.7253	152.9959	.2	2307.2225	
	1870.383	153.3101	.3	2315.744	
	1878.0563	153.6242	.4	2324.2813	
	1885.7454	153.9384	.5	2332.8343	
	1893.4502	154.2526	.6	2341.4031	
	1901.1707	154.5667	.7	2349.9875	
	1908.9068	154.8809	.8	2358.5876	
	1916.6587	155.195	.9	2367.2035	

Diam.	Area.	Circum.	Diam.	Area.	Circum.
8	6082.1376	276.4608	.5	6866.1631	293.7396
.1	6095.9685	276.775	.6	6880.858	294.0538
.2	6109.8151	277.0891	.7	6895.5685	294.3679
.3	6123.6774	277.4033	.8	6910.2948	294.6821
.4	6137.5554	277.7174	.9	6925.0367	294.9962
.5	6151.4491	278.0316	94	6939.7944	295.3104
.6	6165.3586	278.3458	.1	6954.5678	295.6246
.7	6179.2837	278.6599	.2	6969.3569	295.9387
.8	6193.2246	278.9741	.3	6984.1616	296.2529
.9	6207.1811	279.2882	.4	6998.9821	296.567
9	6221.1534	279.6024	.5	7013.8183	296.8812
.1	6235.1414	279.9166	.6	7028.6703	297.1954
.2	6249.1451	280.2307	.7	7043.5379	297.5095
.3	6263.1644	280.5449	.8	7058.4212	297.8237
.4	6277.1995	280.859	.9	7073.3203	298.1378
.5	6291.2503	281.1732	95	7088.235	298.452
.6	6305.3169	281.4874	.1	7103.1655	298.7662
.7	6319.3991	281.8015	.2	7118.1116	299.0803
.8	6333.497	282.1157	.3	7133.0735	299.3945
.9	6347.6107	282.4298	.4	7148.0511	299.7086
0	6361.74	282.744	.5	7163.0443	300.0228
.1	6375.8851	283.0582	.6	7178.0533	300.337
.2	6390.0458	283.3723	.7	7193.078	300.6511
.3	6404.2223	283.6865	.8	7208.1185	300.9653
.4	6418.4144	284.0006	.9	7223.1746	301.2794
.5	6432.6223	284.3148	96	7238.2464	301.5936
.6	6446.8459	284.629	.1	7253.3339	301.9078
.7	6461.0852	284.9431	.2	7268.4372	302.2219
.8	6475.3403	285.2573	.3	7283.5561	302.5361
.9	6489.611	285.5714	.4	7298.6908	302.8502
1	6503.8974	285.8856	.5	7313.8411	303.1644
.1	6518.1995	286.1998	.6	7329.0072	303.4786
.2	6532.5174	286.5139	.7	7344.189	303.7927
.3	6546.8509	286.8281	.8	7359.3865	304.1069
.4	6561.2002	287.1422	.9	7374.5997	304.421
.5	6575.5651	287.4564	97	7389.8286	304.7352
.6	6589.9458	287.7706	.1	7405.0732	305.0494
.7	6604.3422	288.0847	.2	7420.3335	305.3635
.8	6618.7543	288.3989	.3	7435.6096	305.6777
.9	6633.1821	288.713	.4	7450.9013	305.9918
	6647.6256	289.0272	.5	7466.2087	306.306
.1	6662.0848	289.3414	.6	7481.5319	306.6202
.2	6676.5598	289.6555	.7	7496.8708	306.9343
.3	6691.0504	289.9697	.8	7512.2253	307.2485
.4	6705.5567	290.2838	.9	7527.5956	307.5626
.5	6720.0787	290.598	98	7542.9816	[illegible]
.6	6734.6165	290.9121	.1	7558.3833	
.7	6749.17	291.2263	.2	7573.8007	
.8	6763.7391	291.5405	.3	7589.2338	
.9	6778.324	291.8546	.4	7604.6826	
	6792.9246	292.1688	.5	7620.1471	
.1	6807.5409	292.483	.6	7635.6274	
.2	6822.1729	292.7971	.7	7651.1233	
.3	6836.8206	293.1113	.8	7666.635	
.4	6851.484	293.4254	.9	7682.1623	

Diam.	Area.	Circum.	Diam.	Area.	Circum.
55	2375.835	172.788	.5	2874.7603	190.0668
.1	2384.4823	173.1022	.6	2884.2715	190.381
.2	2393.1452	173.4163	.7	2893.7984	190.6951
.3	2401.8239	173.7305	.8	2903.3411	191.0093
.4	2410.5183	174.0446	.9	2912.8994	191.3234
.5	2419.2283	174.3588	61	2922.4734	191.6376
.6	2427.9541	174.673	.1	2932.0631	191.9518
.7	2436.6957	174.9871	.2	2941.6686	192.2659
.8	2445.4529	175.3013	.3	2951.2897	192.5801
.9	2454.2258	175.6154	.4	2960.9266	192.8942
56	2463.0144	175.9296	.5	2970.5791	193.2084
.1	2471.8187	176.2438	.6	2980.2474	193.5226
.2	2480.6388	176.5579	.7	2989.9314	193.8367
.3	2489.4745	176.8721	.8	2999.6311	194.1509
.4	2498.326	177.1862	.9	3009.3465	194.465
.5	2507.1931	177.5004	62	3019.0776	194.7792
.6	2516.076	177.8146	.1	3028.8244	195.0934
.7	2524.9736	178.1287	.2	3038.5869	195.4075
.8	2533.8889	178.4429	.3	3048.3652	195.7217
.9	2542.8189	178.757	.4	3058.1591	196.0358
57	2551.7646	179.0712	.5	3067.9687	196.35
.1	2560.726	179.3854	.6	3077.7941	196.6642
.2	2569.7031	179.6995	.7	3087.6341	196.9783
.3	2578.696	180.0137	.8	3097.4919	197.2925
.4	2587.7045	180.3278	.9	3107.3644	197.6066
.5	2596.7287	180.642	63	3117.2526	197.9208
.6	2605.7687	180.9562	.1	3127.1565	198.235
.7	2614.8244	181.2703	.2	3137.0761	198.5491
.8	2623.8957	181.5845	.3	3147.0114	198.8633
.9	2632.9828	181.8986	.4	3156.9624	199.1774
58	2642.0856	182.2128	.5	3166.9291	199.4916
.1	2651.2041	182.527	.6	3176.9116	199.8058
.2	2660.3383	182.8411	.7	3186.9097	200.1199
.3	2669.4882	183.1553	.8	3196.9236	200.4341
.4	2678.6538	183.4694	.9	3206.9531	200.7482
.5	2687.8351	183.7836	64	3216.9984	201.0624
.6	2697.0322	184.0978	.1	3227.0594	201.3766
.7	2706.2449	184.4119	.2	3237.1361	201.6907
.8	2715.4734	184.7261	.3	3247.2284	202.0049
.9	2724.7175	185.0402	.4	3257.3365	202.319
59	2733.9774	185.3544	.5	3267.4603	202.6332
.1	2743.253	185.6686	.6	3277.5999	202.9474
.2	2752.5443	185.9827	.7	3287.7551	203.2615
.3	2761.8512	186.2969	.8	3297.9261	203.5757
.4	2771.1739	186.611	.9	3308.1127	203.8898
5	2780.5123	186.9252	65	3318.315	204.204
	2789.8665	187.2394	.1	3328.5331	204.5182
	2799.2363	187.5535	.2	3338.7668	204.8323
	2808.6218	187.8677	.3	3349.0163	205.1465
	2818.0231	188.1818	.4	3359.2815	205.4606
	2827.44	188.496	.5	3369.5623	205.7748
	2836.8727	188.8102	.6	3379.8589	206.089
	2846.321	189.1243	.7	3390.1712	206.4031
	2855.7851	189.4385	.8	3400.4993	206.7173
	2865.2649	189.7526	.9	3410.843	207.0314

Diam.	Area.	Circum.	Diam.	Area.	Circum.
	3421.2024	207.3456	.5	4015.1611	224.6244
.1	3431.5775	207.6598	.6	4026.4002	224.9386
.2	3441.9684	207.9739	.7	4037.655	225.2527
.3	3452.3749	208.2881	.8	4048.9255	225.5669
.4	3462.7972	208.6022	.9	4060.2117	225.881
.5	3473.2351	208.9164	72	4071.5136	226.1952
.6	3483.6888	209.2306	.1	4082.8312	226.5094
.7	3494.1582	209.5447	.2	4094.1645	226.8235
.8	3504.6433	209.8589	.3	4105.5136	227.1377
.9	3515.1441	210.173	.4	4116.8783	227.4518
	3525.6606	210.4872	.5	4128.2587	227.766
.1	3536.1928	210.8014	.6	4139.655	228.0802
.2	3546.7407	211.1155	.7	4151.0668	228.3943
.3	3557.3044	211.4297	.8	4162.4943	228.7085
.4	3567.8837	211.7438	.9	4173.9376	229.0226
.5	3578.4787	212.058	73	4185.3966	229.3368
.6	3589.0895	212.3722	.1	4196.8713	229.651
.7	3599.716	212.6863	.2	4208.3617	229.9651
8	3610.3581	213.0005	.3	4219.8678	230.2793
9	3621.016	213.3146	.4	4231.3896	230.5934
	3631.6896	213.6288	.5	4242.9271	230.9076
1	3642.3789	213.943	.6	4254.4804	231.2218
2	3653.0839	214.2571	.7	4266.0493	231.5359
3	3663.805	214.5713	.8	4277.634	231.8501
4	3674.541	214.8854	.9	4289.2343	232.1642
5	3685.2931	215.1996	74	4300.8504	232.4784
5	3696.061	215.5138	.1	4312.4822	232.7926
7	3706.8445	215.8279	.2	4324.1297	233.1067
3	3717.6438	216.1421	.3	4335.7928	233.4209
	3728.4587	216.4562	.4	4347.4717	233.735
	3739.2894	216.7704	.5	4359.1663	234.0492
	3750.1358	217.0846	.6	4370.8767	234.3634
	3760.9979	217.3987	.7	4382.6027	234.6775
	3771.8756	217.7129	.8	4394.3444	234.9917
	3782.7691	218.027	.9	4406.1019	235.3058
	3793.6783	218.3412	75	4417.875	235.62
	3804.6033	218.6554	.1	4429.6639	235.9342
	3815.5439	218.9695	.2	4441.4684	236.2483
	3826.5002	219.2837	.3	4453.2887	236.5625
	3837.4722	219.5978	.4	4465.1247	236.8766
	3848.46	219.912	.5	4476.9763	237.1908
	3859.4635	220.2262	.6	4488.8437	237.505
	3870.4826	220.5403	.7	4500.7268	237.8191
	3881.5175	220.8545	.8	4512.6257	238.1333
	3892.5681	221.1686	.9	4524.5402	238.4474
	3903.6343	221.4828	76	4536.4704	238.7616
	3914.7163	221.797	.1	4548.4163	[illegible]0758
	3925.814	222.1111	.2	4560.378	[illegible]399
	3936.9275	222.4253	.3	4572.355[illegible]	[illegible]
	3948.9566	222.7394	.4	4584.348[illegible]	
	3959.2014	223.0536	.5	4596.357[illegible]	
	3970.3619	223.3678	.6	4608.381[illegible]	
	3981.5382	223.6819	.7	4620.421[illegible]	
	3992.7301	223.9961	.8	4632.477[illegible]	
	4003.9378	224.3102	.9	4644.5493	

Diam.	Area.	Circum.	Diam.	Area.	Circum.
77	4656.6366	241.9032	.5	5345.6287	259.182
.1	4668.7396	242.2174	.6	5358.5957	259.4962
.2	4680.8583	242.5315	.7	5371.5784	259.8103
.3	4692.9928	242.8457	.8	5384.5767	260.1245
.4	4705.1429	243.1598	.9	5397.5908	260.4386
.5	4717.3087	243.474	83	5410.6206	260.7528
.6	4729.4903	243.7882	.1	5423.6661	261.067
.7	4741.6876	244.1023	.2	5436.7273	261.3811
.8	4753.9005	244.4165	.3	5449.8042	261.6953
.9	4766.1292	244.7306	.4	5462.8968	262.0094
78	4778.3736	245.0448	.5	5476.0051	262.3236
.1	4790.6337	245.359	.6	5489.1292	262.6378
.2	4802.9095	245.6731	.7	5502.2689	262.9519
.3	4815.201	245.9873	.8	5515.4244	263.2661
.4	4827.5082	246.3014	.9	5528.5955	263.5802
.5	4839.8311	246.6156	84	5541.7824	263.8944
.6	4852.1698	246.9298	.1	5554.985	264.2086
.7	4864.5241	247.2439	.2	5568.2033	264.5227
.8	4876.8942	247.5581	.3	5581.4372	264.8369
.9	4889.2799	247.8722	.4	5594.6869	265.151
79	4901.6814	248.1864	.5	5607.9523	265.4652
.1	4914.0986	248.5006	.6	5621.2335	265.7794
.2	4926.5315	248.8147	.7	5634.5303	266.0935
.3	4938.98	249.1289	.8	5647.8428	266.4077
.4	4951.4443	249.443	.9	5661.1711	266.7218
.5	4963.9243	249.7572	85	5674.515	267.036
.6	4976.4201	250.0714	.1	5687.8747	267.3502
.7	4988.9315	250.3855	.2	5701.25	267.6643
.8	5001.4586	250.6997	.3	5714.6411	267.9785
.9	5014.0015	251.0138	.4	5728.0479	268.2926
80	5026.56	251.328	.5	5741.4703	268.6068
.1	5039.1343	251.6422	.6	5754.9085	268.921
.2	5051.7242	251.9563	.7	5768.3624	269.2351
.3	5064.3299	252.2705	.8	5781.8321	269.5493
.4	5076.9513	252.5846	.9	5795.3174	269.8634
.5	5089.5883	252.8988	86	5808.8184	270.1776
.6	5102.2411	253.213	.1	5822.3351	270.4918
.7	5114.9096	253.5271	.2	5835.8676	270.8059
.8	5127.5939	253.8413	.3	5849.4157	271.1201
.9	5140.2938	254.1554	.4	5862.9796	271.4342
81	5153.0094	254.4696	.5	5876.5591	271.7484
.1	5165.7407	254.7838	.6	5890.1544	272.0626
.2	5178.4878	255.0979	.7	5903.7654	272.3767
.3	5191.2505	255.4121	.8	5917.3921	272.6909
.4	5204.0289	255.7262	.9	5931.0345	273.005
.5	5216.8231	256.0404	87	5944.6926	273.3192
.6	5229.633	256.3546	.1	5958.3644	273.6334
.7	5242.4586	256.6687	.2	5972.0559	273.9475
.8	5255.2999	256.9829	.3	5985.7612	274.2617
.9	5268.1569	257.297	.4	5999.4821	274.5758
82	5281.0296	257.6112	.5	6013.2187	274.89
[illegible]	5293.918	257.9254	.6	6026.9711	275.2042
	[illegible]6.8221	258.2395	.7	6040.7392	275.5183
	[illegible]42	258.5537	.8	6054.5229	275.8325
	[illegible]775	258.8678	.9	6068.3224	276.1466

Area.	Circum.	Diam.	Area.	Circum.
6082.1376	276.4608	.5	6866.1631	293.7396
6095.9685	276.775	.6	6880.858	294.0538
6109.8151	277.0891	.7	6895.5685	294.3679
6123.6774	277.4033	.8	6910.2948	294.6821
6137.5554	277.7174	.9	6925.0367	294.9962
6151.4491	278.0316	94	6939.7944	295.3104
6165.3586	278.3458	.1	6954.5678	295.6246
6179.2837	278.6599	.2	6969.3569	295.9387
6193.2246	278.9741	.3	6984.1616	296.2529
6207.1811	279.2882	.4	6998.9821	296.567
6221.1534	279.6024	.5	7013.8183	296.8812
6235.1414	279.9166	.6	7028.6703	297.1954
6249.1451	280.2307	.7	7043.5379	297.5095
6263.1644	280.5449	.8	7058.4212	297.8237
6277.1995	280.859	.9	7073.3203	298.1378
6291.2503	281.1732	95	7088.235	298.452
6305.3169	281.4874	.1	7103.1655	298.7662
6319.3991	281.8015	.2	7118.1116	299.0803
6333.497	282.1157	.3	7133.0735	299.3945
6347.6107	282.4298	.4	7148.0511	299.7086
6361.74	282.744	.5	7163.0443	300.0228
6375.8851	283.0582	.6	7178.0533	300.337
6390.0458	283.3723	.7	7193.078	300.6511
6404.2223	283.6865	.8	7208.1185	300.9653
6418.4144	284.0006	.9	7223.1746	301.2794
6432.6223	284.3148	96	7238.2464	301.5936
6446.8459	284.629	.1	7253.3339	301.9078
6461.0852	284.9431	.2	7268.4372	302.2219
6475.3403	285.2573	.3	7283.5561	302.5361
6489.611	285.5714	.4	7298.6908	302.8502
6503.8974	285.8856	.5	7313.8411	303.1644
6518.1995	286.1998	.6	7329.0072	303.4786
6532.5174	286.5139	.7	7344.189	303.7927
6546.8509	286.8281	.8	7359.3865	304.1069
6561.2002	287.1422	.9	7374.5997	304.421
6575.5651	287.4564	97	7389.8286	304.7352
6589.9458	287.7706	.1	7405.0732	305.0494
6604.3422	288.0847	.2	7420.3335	305.3635
6618.7543	288.3989	.3	7435.6096	305.6777
6633.1821	288.713	.4	7450.9013	305.9918
6647.6256	289.0272	.5	7466.2087	306.306
6662.0848	289.3414	.6	7481.5319	306.6202
6676.5598	289.6555	.7	7496.8708	306.9343
6691.0504	289.9697	.8	7512.2253	307.2485
6705.5567	290.2838	.9	7527.5956	307.5626
6720.0787	290.598	98	7542.9816	307.8768
6734.6165	290.9121	.1	7558.3833	308.191
6749.17	291.2263	.2	7573.8007	308.5051
6763.7391	291.5405	.3	7589.2338	
6778.324	291.8546	.4	7604.6826	
6792.9246	292.1688	.5	7620.1471	
6807.5409	292.483	.6	7635.6274	
6822.1729	292.7971	.7	7651.1233	
6836.8206	293.1113	.8	7666.635	
6851.484	293.4254	.9	7682.1623	

Area.	Circum.	Diam.	Area.	C
7697.7054	311.0184	.5	7775.6563	31
7713.2642	311.3326	.6	7791.2937	31
7728.8337	311.6467	.7	7806.9467	31
7744.4288	311.9609	.8	7822.6154	31
7760.0347	312.275	.9	7838.2999	31

pute Area or Circumference of a Diameter g than any in preceding Table.

s. pages 235-6 and 241-2.

iameter exceeds 100 *and is less than* 1001.

cimal point, and take out area or circumference as for r removing decimal point, if for an area, two places to rig mference, one place.

—What is area and what circumference of a circle 967 feet

i is 7344.189; hence, for 967 it is 734 418.9; and circumferen and for 967 it is 3037.927.

pute Area and Circumference of a Circle b arithms.

s. pages 236, 242.

reas and Circumferences of Circles.

FROM 1 TO 50 FEET (*advancing by an Inch*).

OR, FROM 1 TO 50 INCHES (*advancing by a Twelfth*).

Area.	Circum.	Diam.	Area.	Ci
Feet.	Feet.		Feet.	
.7854	3.1416	3 *ft.*	7.0686	9
.9217	3.4034	1	7.4668	9
1.069	3.6652	2	7.8758	9
1.2272	3.927	3	8.2958	10
1.3963	4.1888	4	8.7267	10
1.5763	4.4506	5	9.1685	10
1.7671	4.7124	6	9.6211	10
1.969	4.9742	7	10.0848	11
2.1817	5.236	8	10.5593	11
2.4053	5.4978	9	11.0447	11
2.6398	5.7596	10	11.541	12
2.8853	6.0214	11	12.0483	12
3.1416	6.2832	4 *ft.*	12.5664	12
3.4088	6.545	1	13.0955	12
3.687	6.8068	2	13.6354	13
3.9761	7.0686	3	14.1863	13
	7.3304	4	14.7481	13
	7.5922	5	15.3208	13
	7.854	6	15.9043	14
	8.1158	7	16.4989	14
	8.3776	8	17.1043	14
	8.6394	9	17.7206	14
	8.9012	10	18.3478	15
	9.163	11	18.9859	1

Area.	Circum.	Diam.	Area.	Circum.
Feet.	Feet.		Feet.	Feet.
19.635	15.708	6	70.8823	29.8452
20.2949	15.9698	7	72.1314	30.107
20.9658	16.2316	8	73.3913	30.3688
21.6476	16.4934	9	74.6621	30.6306
22.3403	16.7552	10	75.9439	30.8924
23.0439	17.017	11	77.2365	31.1542
23.7583	17.2788	10 *ft.*	78.54	31.416
24.4837	17.5406	1	79.8545	31.6778
25.22	17.8024	2	81.1798	31.9396
25.9673	18.0642	3	82.5161	32.2014
26.7254	18.326	4	83.8633	32.4632
27.4944	18.5878	5	85.2214	32.725
28.2744	18.8496	6	86.5903	32.9868
29.0653	19.1114	7	87.9703	33.2486
29.867	19.3732	8	89.3611	33.5104
30.6797	19.635	9	90.7628	33.7722
31.5033	19.8968	10	92.1754	34.034
32.3378	20.1586	11	93.599	34.2958
33.1831	20.4204	11 *ft.*	95.0334	34.5576
34.0394	20.6822	1	96.4787	34.8194
34.9067	20.944	2	97.935	35.0812
35.7848	21.2058	3	99.4022	35.343
36.6738	21.4676	4	100.8803	35.6048
37.5738	21.7294	5	102.3693	35.8666
38.4846	21.9912	6	103.8691	36.1284
39.4064	22.253	7	105.38	36.3902
40.339	22.5148	8	106.9017	36.652
41.2826	22.7766	9	108.4343	36.9138
42.2371	23.0384	10	109.9778	37.1756
43.2025	23.3002	11	111.5323	37.4374
44.1787	23.562	12 *ft.*	113.0976	37.6992
45.1659	23.8238	1	114.6739	37.961
46.1641	24.0856	2	116.261	38.2228
47.1731	24.3474	3	117.8591	38.4846
48.193	24.6092	4	119.468	38.7464
49.2238	24.871	5	121.088	39.0082
50.2656	25.1328	6	122.7187	39.27
51.3183	25.3946	7	124.3605	39.5318
52.3818	25.6564	8	126.0131	39.7936
53.4563	25.9182	9	127.6766	40.0554
54.5417	26.18	10	129.351	40.3172
55.638	26.4418	11	131.0366	40.579
56.7451	26.7036	13 *ft.*	132.7326	40.8408
57.8632	26.9654	1	134.4398	41.1026
58.9923	27.2272	2	136.1578	41.3644
60.1322	27.489	3	137.8868	
61.283	27.7508	4	139.6267	
62.4448	28.0126	5	141.3774	
63.6174	28.2744	6	143.1391	
64.801	28.5362	7	144.9117	
65.9954	28.798	8	146.6953	
67.2008	29.0598	9	148.4897	
68.417	29.3216	10	150.295	
69.6442	29.5834	11	152.1113	

Diam.	Area.	Circum.	Diam.	Area.	Circum.
	Feet.	Feet.		Feet.	Feet.
14 *ft.*	153.9384	43.9824	6	268.8031	58.1196
1	155.7764	44.2442	7	271.2302	58.3814
2	157.6254	44.506	8	273.6683	58.6432
3	159.4853	44.7678	9	276.1172	58.905
4	161.3561	45.0296	10	278.577	59.1668
5	163.2378	45.2914	11	281.0477	59.4286
6	165.1303	45.5532	19 *ft.*	283.5294	59.6904
7	167.0338	45.815	1	286.0219	59.9522
8	168.9483	46.0768	2	288.5255	60.214
9	170.8736	46.3386	3	291.0398	60.4758
10	172.8098	46.6004	4	293.5651	60.7376
11	174.7569	46.8622	5	296.1012	60.9994
15 *ft.*	176.715	47.124	6	298.6483	61.2612
1	178.684	47.3858	7	301.2064	61.523
2	180.6638	47.6476	8	303.7753	61.7848
3	182.6546	47.9094	9	306.3551	62.0466
4	184.6563	48.1712	10	308.9458	62.3084
5	186.6689	48.433	11	311.5475	62.5702
6	188 6924	48.6948	20 *ft.*	314.16	62.832
7	190.7267	48.9566	1	316.7834	63.0938
8	192.7721	49.2184	2	319.4178	63.3556
9	194.8283	49.4802	3	322.0631	63.6174
10	196.8954	49.742	4	324.7193	63.8792
11	198.9734	50.0038	5	327.3864	64.141
16 *ft.*	201.0624	50.2656	6	330.0643	64.4028
1	203.1622	50.5274	7	332.7532	64.6646
2	205.273	50.7892	8	335.4531	64.9264
3	207.3947	51.051	9	338.1638	65.1882
4	209.5273	51.3128	10	340.8854	65.45
5	211.6707	51.5746	11	343.618	65.7118
6	213.8252	51.8364	21 *ft.*	346.3614	65.9736
7	215.9904	52.0982	1	349.1157	66.2354
8	218.1667	52.36	2	351.881	66.4972
9	220.3538	52.6218	3	354.6572	66.759
10	222.5518	52.8836	4	357.4442	67.0208
11	224.7607	53.1454	5	360.2422	67.2826
17 *ft.*	226.9806	53.4072	6	363.0511	67.5444
1	229.2113	53.669	7	365.8709	67.8062
2	231.453	53.9308	8	368.7017	68.068
3	233.7056	54.1926	9	371.5433	68.3298
4	235.9691	54.4544	10	374.3958	68.5916
5	238.2434	54.7162	11	377.2592	68.8534
6	240.5287	54.978	22 *ft.*	380.1336	69.1152
7	242.8249	55.2398	1	383.0188	69.377
8	245.1321	55.5016	2	385.915	69.6388
9	247.4501	55.7634	3	388.8221	69.9006
10	249.779	56.0252	4	391.74	70.1624
11	252.1188	56.287	5	394.6689	70.4242
[illegible]	[illegible]06	56.5488	6	397.6087	70.686
[illegible]	[illegible]	56.8106	7	400.5594	70.9478
[illegible]	[illegible]	57.0724	8	403.5211	71.2096
[illegible]	[illegible]	57.3342	9	406.4936	71.4714
[illegible]	[illegible]7	57.596	10	409.477	71.7332
[illegible]	[illegible]	57.8578	11	412.4713	71.995

Diam.	Area.	Circum.	Diam.	Area.	Circum.
	Feet.	Feet.		Feet.	Feet.
3 *ft.*	415.4766	72.2568	6	593.9587	86.394
1	418.4927	72.5186	7	597.5639	86.6558
2	421.5198	72.7804	8	601.18	86.9176
3	424.5578	73.0422	9	604.8071	87.1794
4	427.6067	73.304	10	608.445	87.4412
5	430.6664	73.5658	11	612.0938	87.703
6	433.7371	73.8276	28 *ft.*	615.7536	87.9648
7	436.8187	74.0894	1	619.4242	88.2266
8	439.91	74.3512	2	623.1058	88.4884
9	443.0147	74.613	3	626.7983	88.7502
10	446.129	74.8748	4	630.5016	89.012
11	449.2542	75.1366	5	634.2159	89.2738
4 *ft.*	452.3904	75.3984	6	637.9411	89.5356
1	455.5374	75.6602	7	641.6772	89.7974
2	458.6954	75.922	8	645.4243	90.0592
3	461.8643	76.1838	9	649.1822	90.321
4	465.044	76.4456	10	652.951	90.5828
5	468.2347	76.7074	11	656.7307	90.8446
6	471.4363	76.9692	29 *ft.*	660.5214	91.1064
7	474.6488	77.231	1	664.3229	91.3682
8	477.8723	77.4928	2	668.1354	91.63
9	481.1066	77.7546	3	671.9588	91.8918
10	484.3518	78.0164	4	675.7931	92.1536
11	487.6076	78.2782	5	679.6382	92.4154
ft.	490.875	78.54	6	683.4943	92.6772
1	494.1529	78.8018	7	687.3613	92.939
2	497.4418	79.0636	8	691.2393	93.2008
3	500.7416	79.3254	9	695.1281	93.4626
4	504.0523	79.5872	10	699.0278	93.7244
5	507.3738	79.849	11	702.9384	93.9862
6	510.7063	80.1108	30 *ft.*	706.86	94.248
7	514.0485	80.3726	1	710.7924	94.5098
8	517.404	80.6344	2	714.7358	94.7716
9	520.7693	80.8962	3	718.6901	95.0334
10	524.1454	81.158	4	722.6553	95.2952
11	527.5324	81.4198	5	726.6313	95.557
ft.	530.9304	81.6816	6	730.6183	95.8188
1	534.3397	81.9434	7	734.6162	96.0806
2	537.759	82.2052	8	738.6251	96.3424
3	541.1897	82.467	9	742.6448	96.6042
4	544.6313	82.7288	10	746.6754	96.866
5	548.0837	82.9906	11	750.7164	97.1278
6	551.5471	83.2524	31 *ft.*	754.7694	97.3896
7	555.0214	83.5142	1	758.8327	97.6514
8	558.5066	83.776	2	762.907	97.9132
9	562.0028	84.0378	3	766.9922	98.175
10	565.5098	84.2996	4	771.0883	[illegible]
11	569.0277	84.5614	5	775.1952	
ft.	572.5566	84.8232	6	779.3131	
1	576.0963	85.085	7	783.4419	
2	579.6467	85.3468	8	787.5817	
3	583.2086	85.6086	9	791.7323	
4	586.781	85.8704	10	795.8938	
5	590.3644	86.1322	11	800.0662	

DIAM.	AREA.	CIRCUM.
	Feet.	Feet.
32 *ft.*	804.2496	100.5312
1	808.4439	100.793
2	812.649	101.0548
3	816.8651	101.3166
4	821.092	101.5784
5	825.3299	101.8402
6	829.5787	102.102
7	833.8384	102.3638
8	838.1091	102.6256
9	842.3906	102.8874
10	846.683	103.1492
11	850.9863	103.411
33 *ft.*	855.3006	103.6728
1	859.6257	103.9346
2	863.9618	104.1964
3	868.3088	104.4582
4	872.6667	104.72
5	877.0354	104.9818
6	881.4151	105.2436
7	885.8057	105.5054
8	890.2073	105.7672
9	894.6197	106.029
10	899.043	106.2908
11	903.4772	106.5526
34 *ft.*	907.9224	106.8144
1	912.3784	107.0762
2	916.8454	107.338
3	921.3233	107.5998
4	925.812	107.8616
5	930.3117	108.1234
6	934.8223	108.3852
7	939.3439	108.647
8	943.8763	108.9088
9	948.4196	109.1706
10	952.9738	109.4324
11	957.5392	109.6942
35 *ft.*	962.115	109.956
1	966.7019	110.2178
2	971.2998	110.4796
3	975.9086	110.7414
4	980.5287	111.0032
5	985.1588	111.265
6	989.8005	111.5268
7	994.4527	111.7886
8	999.116	112.0504
9	1003.7903	112.3122
10	1008.4754	112.574
	1013.1714	112.8358
	1017.8784	113.0976
	1022.5962	113.3594
	1027.325	113.6212
	1032.0647	113.883
	1036.8153	114.1448
	1041.5767	114.4066

DIAM.	AREA.
	Feet.
6	1046.3491
7	1051.1324
8	1055.9266
9	1060.7318
10	1065.5478
11	1070.3747
37 *ft.*	1075.2126
1	1080.0613
2	1084.921
3	1089.7916
4	1094.6731
5	1099.5654
6	1104.4687
7	1109.3829
8	1114.308
9	1119.2441
10	1124.191
11	1129.1489
38 *ft.*	1134.1176
1	1139.0972
2	1144.0878
3	1149.0893
4	1154.1017
5	1159.1249
6	1164.1591
7	1169.2042
8	1174.2603
9	1179.3272
10	1184.405
11	1189.4937
39 *ft.*	1194.5934
1	1199.7039
2	1204.8254
3	1209.9578
4	1215.101
5	1220.2552
6	1225.4203
7	1230.5963
8	1235.7833
9	1240.9811
10	1246.1898
11	1251.4094
40 *ft.*	1256.64
1	1261.8814
2	1267.1338
3	1272.3971
4	1277.6712
5	1282.9563
6	1288.2523
7	1293.5592
8	1298.877
9	1304.2058
10	1309.5454
11	1314.8959

Diam.	Area.	Circum.	Diam.	Area.	Circum.
	Feet.	Feet.		Feet.	Feet.
1 *ft.*	1320.2574	128.8056	6	1625.9743	142.9428
1	1325.6297	129.0674	7	1631.9357	143.2046
2	1331.013	129.3292	8	1637.9081	143.4664
3	1336.4072	129.591	9	1643.8913	143.7282
4	1341.8123	129.8528	10	1649.8854	143.99
5	1347.2282	130.1146	11	1655.8904	144.2518
6	1352.6551	130.3764	46 *ft.*	1661.9064	144.5136
7	1358.0929	130.6382	1	1667.9332	144.7754
8	1363.5416	130.9	2	1673.971	145.0372
9	1369.0013	131.1618	3	1680.0197	145.299
10	1374.4718	131.4236	4	1686.0792	145.5608
11	1379.9532	131.6854	5	1692.1497	145.8226
ı *ft.*	1385.4456	131.9472	6	1698.2311	146.0844
1	1390.9488	132.209	7	1704.3195	146.3462
2	1396.463	132.4708	8	1710.4267	146.608
3	1401.9881	132.7326	9	1716.5408	146.8698
4	1407.5241	132.9944	10	1722.6658	147.1316
5	1413.0709	133.2562	11	1728.8017	147.3934
6	1418.6287	133.518	47 *ft.*	1734.9486	147.6552
7	1424.1974	133.7798	1	1741.1063	147.917
8	1429.777	134.0416	2	1747.275	148.1788
9	1435.3676	134.3034	3	1753.4546	148.4406
10	1440.969	134.5652	4	1759.6451	148.7024
11	1446.5813	134.827	5	1765.8464	148.9642
ft.	1452.2046	135.0888	6	1772.0587	149.226
1	1457.8387	135.3506	7	1778.2819	149.4878
2	1463.4838	135.6124	8	1784.516	149.7496
3	1469.1398	135 8742	9	1790.7611	150.0114
4	1474.8066	136.136	10	1797.017	150.2732
5	1480.4844	136.3978	11	1803.2838	150.535
6	1486.1731	136.6596	48 *ft.*	1809.5616	150.7968
7	1491.8717	136.9214	1	1815.8502	151.0586
8	1497.5833	137.1832	2	1822.1498	151.3204
9	1503.3047	137.445	3	1828.4603	151.5822
10	1509.037	137.7068	4	1834.7817	151.844
11	1514.7802	137.9686	5	1841.1139	152.1058
ft.	1520.5344	138.2304	6	1847.4571	152.3676
1	1526.2994	138.4922	7	1853.8112	152.6294
2	1532.0754	138.754	8	1860.1763	152.8912
3	1537.8623	139.0158	9	1866.5522	153.153
4	1543.66	139.2776	10	1872.939	153.4148
5	1549.4687	139.5394	11	1879.3367	153 6766
6	1555.2883	139.8012	49 *ft.*	1885.7454	153.9384
7	1561.1188	140.063	1	1892.1649	154.2002
8	1566.9603	140.3248	2	1898.5954	154.462
9	1572.8126	140.5866	3	1905.0368	154.7238
10	1578.6756	140.8484	4	1911.480	·54.9856
11	1584.5499	141.1102	5	1917.9	5.2474
ft.	1590.435	141.372	6	1924.4	[illegible]
1	1596.3309	141.6338	7	1930.9	
2	1602.2378	141.8956	8	1937.4	
3	1608.1556	142.1574	9	1943.9	
4	1614.0843	142.4192	10	1950.4	
5	1620.0238	142.681	11	1956.9	
			50 *ft.*	1963.5	

Sides of Squares—equal in Area to a Cir

Diameter from 1 to 100.

Diam.	Side of Sq.	Diam.	Side of Sq.	Diam.	Side of Sq.	Diam.	S
1	.8862	14	12.4072	27	23.9281	40	3
¼	1.1078	¼	12.6287	¼	24.1497	¼	3
½	1.3293	½	12.8503	½	24.3712	½	3
¾	1.5509	¾	13.0718	¾	24.5928	¾	3
2	1.7724	15	13.2934	28	24.8144	41	3
¼	1.994	¼	13.515	¼	25.0359	¼	3
½	2.2156	½	13.7365	½	25.2575	½	3
¾	2.4371	¾	13.9581	¾	25.479	¾	3
3	2.6587	16	14.1796	29	25.7006	42	3
¼	2.8802	¼	14.4012	¼	25.9221	¼	3
½	3.1018	½	14.6227	½	26.1437	½	3
¾	3.3233	¾	14.8443	¾	26.3653	¾	3
4	3.5449	17	15.0659	30	26.5868	43	3
¼	3.7665	¼	15.2874	¼	26.8084	¼	3
½	3.988	½	15.509	½	27.0299	½	3
¾	4.2096	¾	15.7305	¾	27.2515	¾	3
5	4.4311	18	15.9521	31	27.473	44	3
¼	4.6527	¼	16.1736	¼	27.6946	¼	3
½	4.8742	½	16.3952	½	27.9161	½	3
¾	5.0958	¾	16.6168	¾	28.1377	¾	3
6	5.3174	19	16.8383	32	28.3593	45	3
¼	5.5389	¼	17.0599	¼	28.5808	¼	4
½	5.7605	½	17.2814	½	28.8024	½	4
¾	5.982	¾	17.503	¾	29.0239	¾	4
7	6.2036	20	17.7245	33	29.2455	46	4
¼	6.4251	¼	17.9461	¼	29.467	¼	4
½	6.6467	½	18.1677	½	29.6886	½	4
¾	6.8683	¾	18.3892	¾	29.9102	¾	4
8	7.0898	21	18.6108	34	30.1317	47	4
¼	7.3114	¼	18.8323	¼	30.3533	¼	4
½	7.5329	½	19.0539	½	30.5748	½	4
¾	7.7545	¾	19.2754	¾	30.7964	¾	4
9	7.976	22	19.497	35	31.0179	48	4
¼	8.1976	¼	19.7185	¼	31.2395	¼	4
½	8.4192	½	19.9401	½	31.4611	½	4
¾	8.6407	¾	20.1617	¾	31.6826	¾	4
10	8.8623	23	20.3832	36	31.9042	49	4
¼	9.0838	¼	20.6048	¼	32.1257	¼	4
½	9.3054	½	20.8263	½	32.3473	½	4
¾	9.5269	¾	21.0479	¾	32.5688	¾	4
11	9.7485	24	21.2694	37	32.7904	50	4
¼	9.97	¼	21.491	¼	33.0112	¼	4
½	10.1916	½	21.7126	½	33.2335	½	4
¾	10.4132	¾	21.9341	¾	33.4551	¾	4
12	10.6347	25	22.1557	38	33.6766	51	4
¼	10.8563	¼	22.3772	¼	33.8982	¼	4
½	11.0778	½	22.5988	½	34.1197	½	4
¾	11.2994	¾	22.8203	¾	34.3413	¾	4
13	11.5209	26	23.0419	39	34.5628	52	4
¼	11.7425	¼	23.2634	¼	34.7884	¼	4
½	11.9641	½	23.485	½	35.006	½	4
¾	12.1856	¾	23.7066	¾	35.2275	¾	

Diam.	Side of Sq.	Diam.	Side of Sq.	Diam.	Side of Sq.
65	57.6047	77	68.2395	89	78.8742
¼	57.8263	¼	68.461	¼	79.0957
½	58.0479	½	68.6826	½	79.3173
¾	58.2694	¾	68.9041	¾	79.5389
66	58.491	78	69.1257	90	79.7604
¼	58.7125	¼	69.3473	¼	79.982
½	58.9341	½	69.5688	½	80.2035
¾	59.1556	¾	69.7904	¾	80.4251
67	59.3772	79	70.0119	91	80.6467
¼	59.5988	¼	70.2335	¼	80.8682
½	59.8203	½	70.455	½	81.0898
¾	60.0419	¾	70.6766	¾	81.3113
68	60.2634	80	70.8981	92	81.5329
¼	60.485	¼	71.1197	¼	81.7544
½	60.7065	½	71.3413	½	81.976
¾	60.9281	¾	71.5628	¾	82.1975
69	61.1497	81	71.7844	93	82.4191
¼	61.3712	¼	72.0059	¼	82.6407
½	61.5928	½	72.2275	½	82.8622
¾	61.8143	¾	72.4491	¾	83.0838
70	62.0359	82	72.6706	94	83.3053
¼	62.2574	¼	72.8921	¼	83.5269
½	62.479	½	73.1137	½	83.7484
¾	62.7006	¾	73.3353	¾	83.97
71	62.9221	83	73.5568	95	84.1916
¼	63.1437	¼	73.7784	¼	84.4131
½	63.3652	½	73.9999	½	84.6347
¾	63.5868	¾	74.2215	¾	84.8562
72	63.8083	84	74.4431	96	85.0778
¼	64.0299	¼	74.6647	¼	85.2993
½	64.2514	½	74.8862	½	85.5209
¾	64.4730	¾	75.1077	¾	85.7425
73	64.6946	85	75.3293	97	85.9646
¼	64.9161	¼	75.5508	¼	86.185
½	65.1377	½	75.7724	½	86.4071
¾	65.3592	¾	75.9934	¾	86.6289
74	65.5808	86	76.2155	98	86.8502
¼	65.8023	¼	76.4371	¼	87.0718
½	66.0239	½	76.6586	½	87.2933
¾	66.2455	¾	76.8802	¾	87.5449
75	66.467	87	77.1017	99	87.7364
¼	66.6886	¼	77.3233	¼	87.958
½	66.9104	½	77.5449	½	88.1796
¾	67.1317	¾	77.7664	¾	88.4011
76	67.3532	88	77.988		
¼	67.5748	¼	78.2095		
½	67.7964	½	78.4316		
¾	68.0179	¾	78.6526	100	88.6227

Application of Table.

n a Square that has same Area as a Given Circle.

of a square that has same area as a circle of 73.25 ins. is required
eas, page 233, opposite to 73.25 is 4214.11; and in this tab
ide of a square having same area as a circle of that diamet

Lengths of Circular Arcs, up to a Semicircle.

Diameter of a Circle = 1, and divided into 1000 equal Parts.

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
.1	1.02645	.15	1.05896	.2	1.10348	.25	1.15912	.3	1.2249
.101	1.02698	.151	1.05973	.201	1.10447	.251	1.16033	.301	1.2263
.102	1.02752	.152	1.06051	.202	1.10548	.252	1.16157	.302	1.2277
.103	1.02806	.153	1.0613	.203	1.1065	.253	1.16279	.303	1.2291
.104	1.0286	.154	1.06209	.204	1.10752	.254	1.16402	.304	1.2306
.105	1.02914	.155	1.06288	.205	1.10855	.255	1.16526	.305	1.2320
.106	1.0297	.156	1.06368	.206	1.10958	.256	1.16649	.306	1.2334
.107	1.03026	.157	1.06449	.207	1.11062	.257	1.16774	.307	1.2349
.108	1.03082	.158	1.0653	.208	1.11165	.258	1.16899	.308	1.2363
.109	1.03139	.159	1.06611	.209	1.11269	.259	1.17024	.309	1.2378
.11	1.03196	.16	1.06693	.21	1.11374	.26	1.1715	.31	1.2392
.111	1.03254	.161	1.06775	.211	1.11479	.261	1.17275	.311	1.2407
.112	1.03312	.162	1.06858	.212	1.11584	.262	1.17401	.312	1.2421
.113	1.03371	.163	1.06941	.213	1.11692	.263	1.17527	.313	1.2436
.114	1.0343	.164	1.07025	.214	1.11796	.264	1.17655	.314	1.2450
.115	1.0349	.165	1.07109	.215	1.11904	.265	1.17784	.315	1.2465
.116	1.03551	.166	1.07194	.216	1.12011	.266	1.17912	.316	1.2480
.117	1.03611	.167	1.07279	.217	1.12118	.267	1.1804	.317	1.2494
.118	1.03672	.168	1.07365	.218	1.12225	.268	1.18162	.318	1.2509
.119	1.03734	.169	1.07451	.219	1.12334	.269	1.18294	.319	1.2524
.12	1.03797	.17	1.07537	.22	1.12445	.27	1.18428	.32	1.2539
.121	1.0386	.171	1.07624	.221	1.12556	.271	1.18557	.321	1.255
.122	1.03923	.172	1.07711	.222	1.12663	.272	1.18688	.322	1.256
.123	1.03987	.173	1.07799	.223	1.12774	.273	1.18819	.323	1.258
.124	1.04051	.174	1.07888	.224	1.12885	.274	1.18969	.324	1.259
.125	1.04116	.175	1.07977	.225	1.12997	.275	1.19082	.325	1.261
.126	1.04181	.176	1.08066	.226	1.13108	.276	1.19214	.326	1.262
.127	1.04247	.177	1.08156	.227	1.13219	.277	1.19345	.327	1.264
.128	1.04313	.178	1.08246	.228	1.13331	.278	1.19477	.328	1.265
.129	1.0438	.179	1.08337	.229	1.13444	.279	1.1961	.329	1.267
.13	1.04447	.18	1.08428	.23	1.13557	.28	1.19743	.33	1.268
.131	1.04515	.181	1.08519	.231	1.13671	.281	1.19887	.331	1.270
.132	1.04584	.182	1.08611	.232	1.13786	.282	1.20011	.332	1.271
.133	1.04652	.183	1.08704	.233	1.13903	.283	1.20146	.333	1.273
.134	1.04722	.184	1.08797	.234	1.1402	.284	1.20282	.334	1.275
.135	1.04792	.185	1.0889	.235	1.14136	.285	1.20419	.335	1.276
.136	1.04862	.186	1.08984	.236	1.14247	.286	1.20558	.336	1.278
.137	1.04932	.187	1.09079	.237	1.14363	.287	1.20696	.337	1.279
.138	1.05003	.188	1.09174	.238	1.1448	.288	1.20828	.338	1.281
.139	1.05075	.189	1.09269	.239	1.14597	.289	1.20967	.339	1.282
.14	1.05147	.19	1.09365	.24	1.14714	.29	1.21202	.34	1.284
.141	1.0522	.191	1.09461	.241	1.14831	.291	1.21239	.341	1.285
.142	1.05293	.192	1.09557	.242	1.14949	.292	1.21381	.342	1.287
.143	1.05367	.193	1.09654	.243	1.15067	.293	1.2152	.343	1.288
.144	1.05441	.194	1.09752	.244	1.15186	.294	1.21658	.344	1.29
.145	1.05516	.195	1.0985	.245	1.15308	.295	1.21794	.345	1.29
.146	1.05591	.196	1.09949	.246	1.15429	.296	1.21926	.346	1.29
.147	1.05667	.197	1.10048	.247	1.15549	.297	1.22061	.347	1.29
.148	1.05743	.198	1.10147	.248	1.1567	.298	1.22203	.348	1.29
.149	1.05819	.199	1.10247	.249	1.15791	.299	1.22347	.349	1.2

ht.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
5	1.299 97	.38	1.348 99	.41	1.400 77	.44	1.455 12	.47	1.511 85
51	1.301 56	.381	1.350 68	.411	1.402 54	.441	1.456 97	.471	1.513 78
52	1.303 15	.382	1.352 37	.412	1.404 32	.442	1.458 83	.472	1.515 71
53	1.304 74	.383	1.354 06	.413	1.406 1	.443	1.460 69	.473	1.517 64
54	1.306 34	.384	1.355 75	.414	1.407 88	.444	1.462 55	.474	1.519 58
55	1.307 94	.385	1.357 44	.415	1.409 66	.445	1.464 41	.475	1.521 52
56	1.309 54	.386	1.359 14	.416	1.411 45	.446	1.466 28	.476	1.523 46
57	1.311 15	.387	1.360 84	.417	1.413 24	.447	1.468 15	.477	1.525 41
58	1.312 76	.388	1.362 54	.418	1.415 03	.448	1.470 02	.478	1.527 36
59	1.314 37	.389	1.364 25	.419	1.416 82	.449	1.471 89	.479	1.529 31
	1.315 99	.39	1.365 96	.42	1.418 61	.45	1.473 77	.48	1.531 26
1	1.317 61	.391	1.367 67	.421	1.420 41	.451	1.475 65	.481	1.533 22
2	1.319 23	.392	1.369 39	.422	1.422 22	.452	1.477 53	.482	1.535 18
3	1.320 86	.393	1.371 11	.423	1.424 02	.453	1.479 42	.483	1.537 14
4	1.322 49	.394	1.372 83	.424	1.425 83	.454	1.481 31	.484	1.539 1
5	1.324 13	.395	1.374 55	.425	1.427 64	.455	1.483 2	.485	1.541 06
6	1.325 77	.396	1.376 28	.426	1.429 45	.456	1.485 09	.486	1.543 02
7	1.327 41	.397	1.378 01	.427	1.431 27	.457	1.486 99	.487	1.544 99
8	1.329 05	.398	1.379 74	.428	1.433 09	.458	1.488 89	.488	1.546 96
9	1.330 69	.399	1.381 48	.429	1.434 91	.459	1.490 79	.489	1.548 93
	1.332 34	.4	1.383 22	.43	1.436 73	.46	1.492 69	.49	1.550 9
1	1.333 99	.401	1.384 96	.431	1.438 56	.461	1.494 6	.491	1.552 88
2	1.335 64	.402	1.386 71	.432	1.440 39	.462	1.496 51	.492	1.554 86
3	1.337 3	.403	1.388 46	.433	1.442 22	.463	1.498 42	.493	1.556 85
4	1.338 96	.404	1.390 21	.434	1.444 05	.464	1.500 33	.494	1.558 54
5	1.340 63	.405	1.391 96	.435	1.445 89	.465	1.502 24	.495	1.560 83
6	1.342 29	.406	1.393 72	.436	1.447 73	.466	1.504 16	.496	1.562 82
7	1.343 96	.407	1.395 48	.437	1.449 57	.467	1.506 08	.497	1.564 81
8	1.345 63	.408	1.397 24	.438	1.451 42	.468	1.508	.498	1.566 8
9	1.347 31	.409	1.399	.439	1.453 27	.469	1.509 92	.499	1.568 79
								.5	1.570 79

o Ascertain Length of an Arc of a Circle by preceding Table.

Rule.—Divide height by base, find quotient in column of heights, take ngth for that height opposite to it in next column on the right hand. ultiply length thus obtained by base of arc, and product will give length.

Example.—What is length of an arc of a circle, base or span of it being 100 feet, nd height 25?

25 ÷ 100 = .25; and .25, per table, = 1.159 12, *length of base, which, multiplied by* 00 = 115.912 *feet.*

When, in division of a height by base, the quotient has a remainder after hird place of decimals, and great accuracy is required.

Rule.—Take length for first three figures, subtract it from next following ngth; multiply remainder by this fractional remainder, add product to rst length, and sum will give length for whole quotient.

Example.—What is length of an arc of a circle, base of which is 35 feet, and eight or versed sine 8 feet?

8 ÷ 35 = .228 571 4; *tabular length for* .228 = 1.133 31, and for .229 = 1.134 44, *he difference between which is* .001 13. Then .5714 × .001 13 = .000 645 682.

Hence .228 = 1.133 31,
and .000 571 4 = .000 645 682

1.133 955 682, *the sum by which b*
r is to be multiplied; and 1.133 955 682 × 35 = 39.688 45 *feet.*

Side of Sq.	Diam.	Side of Sq.	Diam.	Side of Sq.	Diam.	Side of Sq.
46.97	65	57.6047	77	68.2395	89	78.8742
47.1916	¼	57.8263	¼	68.461	¼	79.0957
47.4131	½	58.0479	½	68.6826	½	79.3173
47.6347	¾	58.2694	¾	68.9041	¾	79.5389
47.8562	66	58.491	78	69.1257	90	79.7604
48.0778	¼	58.7125	¼	69.3473	¼	79.982
48.2994	½	58.9341	½	69.5688	½	80.2035
48.5209	¾	59.1556	¾	69.7904	¾	80.4251
48.7425	67	59.3772	79	70.0119	91	80.6467
48.964	¼	59.5988	¼	70.2335	¼	80.8682
49.1856	½	59.8203	½	70.455	½	81.0898
49.4071	¾	60.0419	¾	70.6766	¾	81.3113
49.6287	68	60.2634	80	70.8981	92	81.5329
49.8503	¼	60.485	¼	71.1197	¼	81.7544
50.0718	½	60.7065	½	71.3413	½	81.976
50.2934	¾	60.9281	¾	71.5628	¾	82.1975
50.5149	69	61.1497	81	71.7844	93	82.4191
50.7365	¼	61.3712	¼	72.0059	¼	82.6407
50.958	½	61.5928	½	72.2275	½	82.8622
51.1796	¾	61.8143	¾	72.4491	¾	83.0838
51.4012	70	62.0359	82	72.6706	94	83.3053
51.6227	¼	62.2574	¼	72.8921	¼	83.5269
51.8443	½	62.479	½	73.1137	½	83.7484
52.0658	¾	62.7006	¾	73.3353	¾	83.97
52.2874	71	62.9221	83	73.5568	95	84.1916
52.5089	¼	63.1437	¼	73.7784	¼	84.4131
52.7305	½	63.3652	½	73.9999	½	84.6347
52.9521	¾	63.5868	¾	74.2215	¾	84.8562
53.1736	72	63.8083	84	74.4431	96	85.0778
53.3952	¼	64.0299	¼	74.6647	¼	85.2993
53.6167	½	64.2514	½	74.8862	½	85.5209
53.8383	¾	64.4730	¾	75.1077	¾	85.7425
54.0598	73	64.6946	85	75.3293	97	85.9646
54.2814	¼	64.9161	¼	75.5508	¼	86.185
54.503	½	65.1377	½	75.7724	½	86.4071
54.7245	¾	65.3592	¾	75.9934	¾	86.6289
54.9461	74	65.5808	86	76.2155	98	86.8502
55.1676	¼	65.8023	¼	76.4371	¼	87.0718
55.3892	½	66.0239	½	76.6586	½	87.2933
55.6107	¾	66.2455	¾	76.8802	¾	87.5449
55.8323	75	66.467	87	77.1017	99	87.7364
56.0538	¼	66.6886	¼	77.3233	¼	87.958
56.2754	½	66.9104	½	77.5449	½	88.1796
56.497	¾	67.1317	¾	77.7664		3.4011
56.7185	76	67.3532	88	77.988		6227
56.9401	¼	67.5748	¼	78.2095		
57.1616	½	67.7964	½	78.4316		
57.3832	¾	68.0179	¾	78.6526		

Application of Table.

scertain a Square that has same Ar Circle.

—If side of a square that has same area as a circle of 7 able of Areas, ***page 233, opposite to*** **73.25 is 4214.11; i** ***which is side of a square having*** **same area as a circle**

Lengths of Circular Arcs, up to a Semicircle.

Diameter of a Circle = 1, and divided into 1000 equal Parts.

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
.1	1.02645	.15	1.05896	.2	1.10348	.25	1.15912	.3	1.22495
.101	1.02698	.151	1.05973	.201	1.10447	.251	1.16033	.301	1.22635
.102	1.02752	.152	1.06051	.202	1.10548	.252	1.16157	.302	1.22776
.103	1.02806	.153	1.0613	.203	1.1065	.253	1.16279	.303	1.22918
.104	1.0286	.154	1.06209	.204	1.10752	.254	1.16402	.304	1.23061
.105	1.02914	.155	1.06288	.205	1.10855	.255	1.16526	.305	1.23205
.106	1.0297	.156	1.06368	.206	1.10958	.256	1.16649	.306	1.23349
.107	1.03026	.157	1.06449	.207	1.11062	.257	1.16774	.307	1.23494
.108	1.03082	.158	1.0653	.208	1.11165	.258	1.16899	.308	1.23636
.109	1.03139	.159	1.06611	.209	1.11269	.259	1.17024	.309	1.2378
.11	1.03196	.16	1.06693	.21	1.11374	.26	1.1715	.31	1.23925
.111	1.03254	.161	1.06775	.211	1.11479	.261	1.17275	.311	1.2407
.112	1.03312	.162	1.06858	.212	1.11584	.262	1.17401	.312	1.24216
.113	1.03371	.163	1.06941	.213	1.11692	.263	1.17527	.313	1.2436
.114	1.0343	.164	1.07025	.214	1.11796	.264	1.17655	.314	1.24506
.115	1.0349	.165	1.07109	.215	1.11904	.265	1.17784	.315	1.24654
.116	1.03551	.166	1.07194	.216	1.12011	.266	1.17912	.316	1.24801
.117	1.03611	.167	1.07279	.217	1.12118	.267	1.1804	.317	1.24946
.118	1.03672	.168	1.07365	.218	1.12225	.268	1.18162	.318	1.25095
.119	1.03734	.169	1.07451	.219	1.12334	.269	1.18294	.319	1.25243
.12	1.03797	.17	1.07537	.22	1.12445	.27	1.18428	.32	1.25391
.121	1.0386	.171	1.07624	.221	1.12556	.271	1.18557	.321	1.25539
.122	1.03923	.172	1.07711	.222	1.12663	.272	1.18688	.322	1.25686
.123	1.03987	.173	1.07799	.223	1.12774	.273	1.18819	.323	1.25836
.124	1.04051	.174	1.07888	.224	1.12885	.274	1.18969	.324	1.25987
.125	1.04116	.175	1.07977	.225	1.12997	.275	1.19082	.325	1.26137
.126	1.04181	.176	1.08066	.226	1.13108	.276	1.19214	.326	1.26286
.127	1.04247	.177	1.08156	.227	1.13219	.277	1.19345	.327	1.26437
.128	1.04313	.178	1.08246	.228	1.13331	.278	1.19477	.328	1.26588
.129	1.0438	.179	1.08337	.229	1.13444	.279	1.1961	.329	1.2674
.13	1.04447	.18	1.08428	.23	1.13557	.28	1.19743	.33	1.26892
.131	1.04515	.181	1.08519	.231	1.13671	.281	1.19887	.331	1.27044
.132	1.04584	.182	1.08611	.232	1.13786	.282	1.20011	.332	1.27196
.133	1.04652	.183	1.08704	.233	1.13903	.283	1.20146	.333	1.27349
.134	1.04722	.184	1.08797	.234	1.1402	.284	1.20282	.334	1.27502
.135	1.04792	.185	1.0889	.235	1.14136	.285	1.20419	.335	1.27656
.136	1.04862	.186	1.08984	.236	1.14247	.286	1.20558	.336	1.2781
.137	1.04932	.187	1.09079	.237	1.14363	.287	1.20696	.337	1.27964
.138	1.05003	.188	1.09174	.238	1.1448	.288	1.20828	.338	1.28118
.139	1.05075	.189	1.09269	.239	1.14597	.289	1.20967	.339	1.28273
.14	1.05147	.19	1.09365	.24	1.14714	.29	1.21202	.34	1.28428
.141	1.0522	.191	1.09461	.241	1.14831	.291	1.21239	.341	1.28583
.142	1.05293	.192	1.09557	.242	1.14949	.292	1.21381	.342	1.28739
.143	1.05367	.193	1.09654	.243	1.15067	.293	1.2152	.343	1.28895
.144	1.05441	.194	1.09752	.244	1.15186	.294	1.21658	.344	1.29052
.145	1.05516	.195	1.0985	.245	1.15308	.295	1.21794	.345	1.29209
[illegible]	[illegible]05591	.196	1.09949	.246	1.15429	.296	1.21926	.346	1.29366
		.197	1.10048	.247	1.15549	.297	1.22061	.347	1.29523
		.198	1.10147	.248	1.1567	.298	1.22203	.348	1.29681
		.199	1.10247	.249	1.15791	.299	1.22347	.349	1.29839

ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
5	1.29997	.38	1.34899	.41	1.40077	.44	.45512	.47	1.51185
51	1.30156	.381	1.35068	.411	1.40254	.441	.45697	.471	1.51378
52	1.30315	.382	1.35237	.412	1.40432	.442	.45883	.472	1.51571
53	1.30474	.383	1.35406	.413	1.4061	.443	.46069	.473	1.51764
54	1.30634	.384	1.35575	.414	1.40788	.444	.46255	.474	1.51958
55	1.30794	.385	1.35744	.415	1.40966	.445	.46441	.475	1.52152
56	1.30954	.386	1.35914	.416	1.41145	.446	.46628	.476	1.52346
57	1.31115	.387	1.36084	.417	1.41324	.447	.46815	.477	1.52541
58	1.31276	.388	1.36254	.418	1.41503	.448	1.47002	.478	1.52736
59	1.31437	.389	1.36425	.419	1.41682	.449	1.47189	.479	1.52931
5	1.31599	.39	1.36596	.42	1.41861	.45	1.47377	.48	1.53126
1	1.31761	.391	1.36767	.421	1.42041	.451	1.47565	.481	1.53322
2	1.31923	.392	1.36939	.422	1.42222	.452	1.47753	.482	1.53518
3	1.32086	.393	1.37111	.423	1.42402	.453	1.47942	.483	1.53714
4	1.32249	.394	1.37283	.424	1.42583	.454	1.48131	.484	1.5391
5	1.32413	.395	1.37455	.425	1.42764	.455	1.4832	.485	1.54106
6	1.32577	.396	1.37628	.426	1.42945	.456	1.48509	.486	1.54302
7	1.32741	.397	1.37801	.427	1.43127	.457	1.48699	.487	1.54499
8	1.32905	.398	1.37974	.428	1.43309	.458	1.48889	.488	1.54696
9	1.33069	.399	1.38148	.429	1.43491	.459	1.49079	.489	1.54893
'	1.33234	.4	1.38322	.43	1.43673	.46	1.49269	.49	1.5509
1	1.33399	.401	1.38496	.431	1.43856	.461	1.4945	.491	1.55288
2	1.33564	.402	1.38671	.432	1.44039	.462	1.49651	.492	1.55486
3	1.3373	.403	1.38846	.433	1.44222	.463	1.49842	.493	1.55685
4	1.33896	.404	1.39021	.434	1.44405	.464	1.50033	.494	1.55854
5	1.34063	.405	1.39196	.435	1.44589	.465	1.50224	.495	1.56083
6	1.34229	.406	1.39372	.436	1.44773	.466	1.50416	.496	1.56282
7	1.34396	.407	1.39548	.437	1.44957	.467	1.50608	.497	1.56481
8	1.34563	.408	1.39724	.438	1.45142	.468	1.508	.498	1.5668
9	1.34731	.409	1.399	.439	1.45327	.469	1.50992	.499	1.56879
								.5	1.57079

› Ascertain Length of an Arc of a Circle by preceding Table.

ʀule.—Divide height by base, find quotient in column of heights, take ɡth for that height opposite to it in next column on the right hand. ltiply length thus obtained by base of arc, and product will give length.

xample.—What is length of an arc of a circle, base or span of it being 100 feet, height 25?

;÷100 = .25; and .25, per table, = 1.15912, ***length of base, which, multiplied by* = 115.912 *feet.***

Vhen, in division of a height by base, the quotient has a remainder after d place of decimals, and great accuracy is required.

ule.—Take length for first three figures, subtract it from next following ɡth; multiply remainder by this fractional remainder, add product to ; length, and sum will give length for whole quotient.

xample.—What is length of an arc of a circle, base of which is 35 feet, and ht or versed sine 8 feet?

÷35 = .2285714; ***tabular length for*** **.228 = 1.13331, a· 229 = 1.13444,**
lifference between which is **.00113. Then .5714 × .001· ·682.**

Hence .228 = 1.13331,
and .0005714 = .000645682

1.133955682

is to be multiplied; and **1.133955682 × 35 = 39.68845**

Lengths of Circular Arcs from 1° to 180°.

(*Radius* = 1.)

Degrees.	Length.	Degrees.	Length.	Degrees.	Length.	Degrees.	Length.
1	.0174	46	.8028	91	1.5882	136	2.3736
2	.0349	47	.8203	92	1.6057	137	2.3911
3	.0524	48	.8377	93	1.6231	138	2.4085
4	.0698	49	.8552	94	1.6406	139	2.426
5	.0873	50	.8727	95	1.6581	140	2.4435
6	.1147	51	.8901	96	1.6755	141	2.4609
7	.1222	52	.9076	97	1.693	142	2.4784
8	.1396	53	.925	98	1.7104	143	2.4958
9	.1571	54	.9424	99	1.7279	144	2.5133
10	.1745	55	.9599	100	1.7453	145	2.5307
11	.192	56	.9774	101	1.7628	146	2.5482
12	.2094	57	.9948	102	1.7802	147	2.5656
13	.2269	58	1.0123	103	1.7977	148	2.5831
14	.2443	59	1.0297	104	1.8151	149	2.6005
15	.2618	60	1.0472	105	1.8326	150	2.618
16	.2792	61	1.0646	106	1.85	151	2.6354
17	.2967	62	1.0821	107	1.8675	152	2.6529
18	.3141	63	1.0995	108	1.8849	153	2.6703
19	.3316	64	1.117	109	1.9024	154	2.6878
20	.3491	65	1.1345	110	1.9199	155	2.7053
21	.3665	66	1.1519	111	1.9373	156	2.7227
22	.384	67	1.1694	112	1.9548	157	2.7402
23	.4014	68	1.1868	113	1.9722	158	2.7576
24	.4189	69	1.2043	114	1.9897	159	2.7751
25	.4363	70	1.2217	115	2.0071	160	2.7925
26	.4538	71	1.2392	116	2.0246	161	2.81
27	.4712	72	1.2566	117	2.042	162	2.8274
28	.4887	73	1.2741	118	2.0595	163	2.8449
29	.5061	74	1.2915	119	2.0769	164	2.8623
30	.5236	75	1.309	120	2.0944	165	2.8798
31	.541	76	1.3264	121	2.1118	166	2.8972
32	.5585	77	1.3439	122	2.1293	167	2.9147
33	.5759	78	1.3613	123	2.1467	168	2.9321
34	.5934	79	1.3788	124	2.1642	169	2.9496
35	.6109	80	1.3963	125	2.1817	170	2.967
36	.6283	81	1.4137	126	2.1991	171	2.9845
37	.6458	82	1.4312	127	2.2166	172	3.002
38	.6632	83	1.4486	128	2.2304	173	3.0194
39	.6807	84	1.4661	129	2.2515	174	3.0369
40	.6981	85	1.4835	130	2.2689	175	3.0543
41	.7156	86	1.501	131	2.2864	176	3.0718
42	.733	87	1.5184	132	2.3038	177	3.0892
43	.7505	88	1.5359	133	2.3213	178	3.1067
44	.7679	89	1.5533	134	2.3387	179	3.1241
45	.7854	90	1.5708	135	2.3562	180	3.1416

Ascertain Length of a Circular Arc by Table.

…om column opposite to degrees of arc, take length, and multi… …f circle.

… degrees in an arc are 45°, and diameter of circle 5 feet.

= 1.9635 feet.

Lengths of Elliptic Arcs.

Up to a Semi-ellipse.

Transverse Diameter = 1, *and divided into* 1000 *equal Parts.*

ht.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
	1.04162	.15	1.0933	.2	1.15014	.25	1.21136	.3	1.27669
01	1.04262	.151	1.09448	.201	1.15131	.251	1.21263	.301	1.27803
02	1.04362	.152	1.09558	.202	1.15248	.252	1.2139	.302	1.27937
03	1.04462	.153	1.09669	.203	1.15366	.253	1.21517	.303	1.28071
04	1.04562	.154	1.0978	.204	1.15484	.254	1.21644	.304	1.28205
05	1.04662	.155	1.09891	.205	1.15602	.255	1.21772	.305	1.28339
06	1.04762	.156	1.10002	.206	1.1572	.256	1.219	.306	1.28474
07	1.04862	.157	1.10113	.207	1.15838	.257	1.22028	.307	1.28609
08	1.04962	.158	1.10224	.208	1.15957	.258	1.22156	.308	1.28744
09	1.05063	.159	1.10335	.209	1.16076	.259	1.22284	.309	1.28879
	1.05164	.16	1.10447	.21	1.16196	.26	1.22412	.31	1.29014
1	1.05265	.161	1.1056	.211	1.16316	.261	1.22541	.311	1.29149
2	1.05366	.162	1.10672	.212	1.16436	.262	1.2267	.312	1.29285
3	1.05467	.163	1.10784	.213	1.16557	.263	1.22799	.313	1.29421
4	1.05568	.164	1.10896	.214	1.16678	.264	1.22928	.314	1.29557
5	1.05669	.165	1.11008	.215	1.16799	.265	1.23057	.315	1.29603
6	1.0577	.166	1.1112	.216	1.1692	.266	1.23186	.316	1.29829
7	1.05872	.167	1.11232	.217	1.17041	.267	1.23315	.317	1.29965
8	1.05974	.168	1.11344	.218	1.17163	.268	1.23445	.318	1.30102
9	1.06076	.169	1.11456	.219	1.17285	.269	1.23575	.319	1.30239
	1.06178	.17	1.11569	.22	1.17407	.27	1.23705	.32	1.30376
1	1.0628	.171	1.11682	.221	1.17529	.271	1.23835	.321	1.30513
2	1.06382	.172	1.11795	.222	1.17651	.272	1.23966	.322	1.3065
3	1.06484	.173	1.11908	.223	1.17774	.273	1.24097	.323	1.30787
4	1.06586	.174	1.12021	.224	1.17897	.274	1.24228	.324	1.30924
5	1.06689	.175	1.12134	.225	1.1802	.275	1.24359	.325	1.31061
5	1.06792	.176	1.12247	.226	1.18143	.276	1.2448	.326	1.31198
7	1.06895	.177	1.1236	.227	1.18266	.277	1.24612	.327	1.31335
3	1.06998	.178	1.12473	.228	1.1839	.278	1.24744	.328	1.31472
[illegible]	1.07001	.179	1.12586	.229	1.18514	.279	1.24876	.329	1.3161
	1.07204	.18	1.12699	.23	1.18638	.28	1.2501	.33	1.31748
[illegible]	1.07308	.181	1.12813	.231	1.18762	.281	1.25142	.331	1.31886
[illegible]	1.07412	.182	1.12927	.232	1.18886	.282	1.25274	.332	1.32024
[illegible]	1.07516	.183	1.13041	.233	1.1901	.283	1.25406	.333	1.32162
[illegible]	1.07621	.184	1.13155	.234	1.19134	.284	1.25538	.334	1.323
[illegible]	1.07726	.185	1.13269	.235	1.19258	.285	1.2567	.335	1.32438
[illegible]	1.07831	.186	1.13383	.236	1.19382	.286	1.25803	.336	1.32576
[illegible]	1.07937	.187	1.13497	.237	1.19506	.287	1.25936	.337	1.32715
[illegible]	1.08043	.188	1.13611	.238	1.1963	.288	1.26069	.338	1.32854
[illegible]	1.08149	.189	1.13726	.239	1.19755	.289	1.26202	.339	1.32993
	1.08255	.19	1.13841	.24	1.1988	.29	1.26335	.34	1.33132
	1.08362	.191	1.13956	.241	1.20005	.291	1.26468	.341	1.33272
	1.08469	.192	1.14071	.242	1.2013	.292	1.26[illegible]	.342	1.33412
	1.08576	.193	1.14186	.243	1.20255	.293	1.[illegible]	.343	1.33552
	1.08684	.194	1.14301	.244	1.2038	.294	1.[illegible]	[illegible]	1.33692
	1.08792	.195	1.14416	.245	1.20506	.295	1.[illegible]	[illegible]	[illegible]833
	1.08901	.196	1.14531	.246	1.20632	.296	1.[illegible]	[illegible]	[illegible]74
	1.0901	.197	1.14646	.247	1.20758	.297	1.[illegible]	[illegible]	[illegible]
	1.09119	.198	1.14762	.248	1.20884	.298	1.[illegible]	[illegible]	[illegible]
	1.09228	.199	1.14888	.249	1.2101	.299	1.[illegible]	[illegible]	[illegible]

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
.35	1.34539	.405	1.42533	.46	1.50842	.515	1.59408	.57	1.68036
.351	1.34681	.406	1.42681	.461	1.50996	.516	1.59564	.571	1.68195
.352	1.34823	.407	1.42829	.462	1.5115	.517	1.5972	.572	1.68354
.353	1.34965	.408	1.42977	.463	1.51304	.518	1.59876	.573	1.68513
.354	1.35108	.409	1.43125	.464	1.51458	.519	1.60032	.574	1.68672
.355	1.35251	.41	1.43273	.465	1.51612	.52	1.60188	.575	1.68831
.356	1.35394	.411	1.43421	.466	1.51766	.521	1.60344	.576	1.6899
.357	1.35537	.412	1.43569	.467	1.5192	.522	1.605	.577	1.69149
.358	1.3568	.413	1.43718	.468	1.52074	.523	1.60656	.578	1.69308
.359	1.35823	.414	1.43867	.469	1.52229	.524	1.60812	.579	1.69467
.36	1.35967	.415	1.44016	.47	1.52384	.525	1.60968	.58	1.69626
.361	1.36111	.416	1.44165	.471	1.52539	.526	1.61124	.581	1.69785
.362	1.36255	.417	1.44314	.472	1.52691	.527	1.6128	.582	1.69945
.363	1.36399	.418	1.44463	.473	1.52849	.528	1.61436	.583	1.70105
.364	1.36543	.419	1.44613	.474	1.53004	.529	1.61592	.584	1.70264
.365	1.36688	.42	1.44763	.475	1.53159	.53	1.61748	.585	1.70424
.366	1.36833	.421	1.44913	.476	1.53314	.531	1.61904	.586	1.70584
.367	1.36978	.422	1.45064	.477	1.53469	.532	1.6206	.587	1.70745
.368	1.37123	.423	1.45214	.478	1.53625	.533	1.62216	.588	1.70905
.369	1.37268	.424	1.45364	.479	1.53781	.534	1.62372	.589	1.71065
.37	1.37414	.425	1.45515	.48	1.53937	.535	1.62528	.59	1.71225
.371	1.37662	.426	1.45665	.481	1.54093	.536	1.62684	.591	1.71286
.372	1.37708	.427	1.45815	.482	1.54249	.537	1.6284	.592	1.71546
.373	1.37854	.428	1.45966	.483	1.54405	.538	1.62996	.593	1.71707
.374	1.38	.429	1.46167	.484	1.54561	.539	1.63152	.594	1.71868
.375	1.38146	.43	1.46268	.485	1.54718	.54	1.63309	.595	1.72029
.376	1.38292	.431	1.46419	.486	1.54875	.541	1.63465	.596	1.7219
.377	1.38439	.432	1.4657	.487	1.55032	.542	1.63623	.597	1.7235
.378	1.38585	.433	1.46721	.488	1.55189	.543	1.6378	.598	1.72511
.379	1.38732	.434	1.46872	.489	1.55346	.544	1.63937	.599	1.72672
.38	1.38879	.435	1.47023	.49	1.55503	.545	1.64094	.6	1.72833
.381	1.39024	.436	1.47174	.491	1.5566	.546	1.64251	.601	1.72994
.382	1.39169	.437	1.47326	.492	1.55817	.547	1.64408	.602	1.73155
.383	1.39314	.438	1.47478	.493	1.55974	.548	1.64565	.603	1.73316
.384	1.39459	.439	1.4763	.494	1.56131	.549	1.64722	.604	1.73477
.385	1.39605	.44	1.47782	.495	1.56289	.55	1.64879	.605	1.73638
.386	1.39751	.441	1.47934	.496	1.56447	.551	1.65036	.606	1.73799
.387	1.39897	.442	1.48086	.497	1.56605	.552	1.65193	.607	1.7396
388	1.40043	.443	1.48238	.498	1.56763	.553	1.6535	.608	1.74121
.389	1.40189	.444	1.48391	.499	1.56921	.554	1.65507	.609	1.74283
.39	1.40335	.445	1.48544	.5	1.57089	.555	1.65665	.61	1.74444
.391	1.40481	.446	1.48697	.501	1.57234	.556	1.65823	.611	1.74605
.392	1.40627	.447	1.4885	.502	1.57389	.557	1.65981	.612	1.74767
.393	1.40773	.448	1.49003	.503	1.57544	.558	1.66139	.613	1.74929
.394	1.40919	.449	1.49157	.504	1.57699	.559	1.66297	.614	1.75091
.395	1.41065	.45	1.49311	.505	1.57854	.56	1.66455	.615	1.75252
06	1.41211	.451	1.49465	.506	1.58009	.561	1.66613	.616	1.75414
[illegible]	1.41357	.452	1.49618	.507	1.58164	.562	1.66771	.617	1.75576
	.41504	.453	1.49771	.508	1.58319	.563	1.66929	.618	1.75738
	.651	.454	1.49924	.509	1.58474	.564	1.67087	.619	1.759
					1.58629	.565	1.67245	.620	1.76062
					1.58784	.566	1.67403	.62	1.76224
					.5894	.567	1.67561	.622	1.76386
					.59096	.568	1.67719	.623	1.76548
					.59252	.569	1.67877	.624	1.7671

gth.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
372	.68	1.85874	.735	1.95059	.79	2.04462	.845	2.14155
034	.681	1.86039	.736	1.95228	.791	2.04635	.846	2.14334
197	.682	1.86205	.737	1.95397	.792	2.04809	.847	2.14513
359	.683	1.8637	.738	1.95566	.793	2.04983	.848	2.14692
521	.684	1.86535	.739	1.95735	.794	2.05157	.849	2.14871
584	.685	1.867	.74	1.95994	.795	2.05331	.85	2.1505
847	.686	1.86866	.741	1.96074	.796	2.05505	.851	2.15229
009	.687	1.87031	.742	1.96244	.797	2.05679	.852	2.15409
172	.688	1.87196	.743	1.96414	.798	2.05853	.853	2.15589
335	.689	1.87362	.744	1.96583	.799	2.06027	.854	2.1577
498	.69	1.87527	.745	1.96753	.8	2.06202	.855	2.1595
66	.691	1.87693	.746	1.96923	.801	2.06377	.856	2.1613
823	.692	1.87859	.747	1.97093	.802	2.06552	.857	2.16309
986	.693	1.88024	.748	1.97262	.803	2.06727	.858	2.16489
149	.694	1.8819	.749	1.97432	.804	2.06901	.859	2.16668
312	.695	1.88356	.75	1.97602	.805	2.07076	.86	2.16848
475	.696	1.88522	.751	1.97772	.806	2.07251	.861	2.17028
038	.697	1.88688	.752	1.97943	.807	2.07427	.862	2.17209
801	.698	1.88854	.753	1.98113	.808	2.07602	.863	2.17389
964	.699	1.8902	.754	1.98283	.809	2.07777	.864	2.1757
127	.7	1.89186	.755	1.98453	.81	2.07953	.865	2.17751
29	.701	1.89352	.756	1.98623	.811	2.08128	.866	2.17932
454	.702	1.89519	.757	1.98794	.812	2.08304	.867	2.18113
517	.703	1.89685	.758	1.98964	.813	2.0848	.868	2.18294
78	.704	1.89851	.759	1.99134	.814	2.08656	.869	2.18475
943	.705	1.90017	.76	1.99305	.815	2.08832	.87	2.18656
107	.706	1.90184	.761	1.99476	.816	2.09008	.871	2.18837
271	.707	1.9035	.762	1.99647	.817	2.09198	.872	2.19018
435	.708	1.90517	.763	1.99818	.818	2.0936	.873	2.192
599	.709	1.90684	.764	1.99989	.819	2.09536	.874	2.19382
763	.71	1.90852	.765	2.0016	.82	2.09712	.875	2.19564
928	.711	1.91019	.766	2.00331	.821	2.09888	.876	2.19746
091	.712	1.91187	.767	2.00502	.822	2.10065	.877	2.19928
255	.713	1.91355	.768	2.00673	.823	2.10242	.878	2.2011
419	.714	1.91523	.769	2.00844	.824	2.10419	.879	2.20292
583	.715	1.91691	.77	2.01016	.825	2.10596	.88	2.20474
747	.716	1.91859	.771	2.01187	.826	2.10773	.881	2.20656
911	.717	1.92027	.772	2.01359	.827	2.1095	.882	2.20839
075	.718	1.92195	.773	2.01531	.828	2.11127	.883	2.21022
24	.719	1.92363	.774	2.01702	.829	2.11304	.884	2.21205
404	.72	1.92531	.775	2.01874	.83	2.11481	.885	2.21388
568	.721	1.927	.776	2.02045	.831	2.11659	.886	2.21571
733	.722	1.92868	.777	2.02217	.832	2.11837	.887	2.21754
897	.723	1.93036	.778	2.02389	.833	2.12015	.888	2.21937
061	.724	1.93204	.779	2.02561	.834	2.12193	.889	2.2212
226	.725	1.93373	.78	2.02733	.835	2.12371	.89	2.22303
391	.726	1.93541	.781	2.02907	.836	2.12549	.891	2.22486
556	.727	1.9371	.782	2.0308	.837	2.12727	[illegible]	[illegible]
72	.728	1.93878	.783	2.03252	.838	2.12905		
885	.729	1.94046	.784	2.03425	.839	2.1308		
05	.73	1.94215	.785	2.03598	.84	2.1326		
215	.731	1.94383	.786	2.03771	.841	2.1343		
379	.732	1.94552	.787	2.03944	.842	2.1361		
544	.733	1.94721	.788	2.04117	.843	2.1379		
709	.734	1.9489	.789	2.0429	.844	2.13976		

Versed Sine.	Seg. Area.	Versed Sine.	Seg. Area.	Versed Sine.	Seg. Area.	Versed Sine.	Seg. Area.	Versed Sine.	Seg.
.256	.15876	.305	.20276	.354	.2488	.403	.29631	.452	[illegible]
.257	.15964	.306	.20368	.355	.24976	.404	.29729	.453	[illegible]
.258	.16051	.307	.2046	.356	.25071	.405	.29827	.454	[illegible]
.259	.16139	.308	.20553	.357	.25167	.406	.29925	.455	[illegible]
.26	.16226	.309	.20645	.358	.25263	.407	.30024	.456	[illegible]
.261	.16314	.31	.20738	.359	.25359	.408	.30122	.457	[illegible]
.262	.16402	.311	.2083	.36	.25455	.409	.3022	.458	[illegible]
.263	.1649	.312	.20923	.361	.25551	.41	.30319	.459	[illegible]
.264	.16578	.313	.21015	.362	.25647	.411	.30417	.46	[illegible]
.265	.16666	.314	.21108	.363	.25743	.412	.30515	.461	[illegible]
.266	.16755	.315	.21201	.364	.25839	.413	.30614	.462	[illegible]
.267	.16844	.316	.21294	.365	.25936	.414	.30712	.463	[illegible]
.268	.16931	.317	.21387	.366	.26032	.415	.30811	.464	[illegible]
.269	.1702	.318	.2148	.367	.26128	.416	.30909	.465	[illegible]
.27	.17109	.319	.21573	.368	.26225	.417	.31008	.466	[illegible]
.271	.17197	.32	.21667	.369	.26321	.418	.31107	.467	[illegible]
.272	.17287	.321	.2176	.37	.26418	.419	.31205	.468	[illegible]
.273	.17376	.322	.21853	.371	.26514	.42	.31304	.469	[illegible]
.274	.17465	.323	.21947	.372	.26611	.421	.31403	.47	[illegible]
.275	.17554	.324	.2204	.373	.26708	.422	.31502	.471	[illegible]
.276	.17643	.325	.22134	.374	.26804	.423	.316	.472	[illegible]
.277	.17733	.326	.22228	.375	.26901	.424	.31699	.473	[illegible]
.278	.17822	.327	.22321	.376	.26998	.425	.31798	.474	[illegible]
.279	.17912	.328	.22415	.377	.27095	.426	.31897	.475	[illegible]
.28	.18002	.329	.22509	.378	.27192	.427	.31996	.476	[illegible]
.281	.18092	.33	.22603	.379	.27289	.428	.32095	.477	[illegible]
.282	.18182	.331	.22697	.38	.27386	.429	.32194	.478	[illegible]
.283	.18272	.332	.22791	.381	.27483	.43	.32293	.479	[illegible]
.284	.18361	.333	.22886	.382	.2758	.431	.32391	.48	[illegible]
.285	.18452	.334	.2298	.383	.27677	.432	.3249	.481	[illegible]
.286	.18542	.335	.23074	.384	.27775	.433	.3259	.482	[illegible]
.287	.18633	.336	.23169	.385	.27872	.434	.32689	.483	[illegible]
.288	.18723	.337	.23263	.386	.27969	.435	.32788	.484	[illegible]
.289	.18814	.338	.23358	.387	.28067	.436	.32887	.485	[illegible]
.29	.18905	.339	.23453	.388	.28164	.437	.32987	.486	[illegible]
.291	.18995	.34	.23547	.389	.28262	.438	.33086	.487	[illegible]
.292	.19086	.341	.23642	.39	.28359	.439	.33185	.488	[illegible]
.293	.19177	.342	.23737	.391	.28457	.44	.33284	.489	[illegible]
.294	.19268	.343	.23832	.392	.28554	.441	.33384	.49	[illegible]
.295	.1936	.344	.23927	.393	.28652	.442	.33483	.491	[illegible]
.296	.19451	.345	.24022	.394	.2875	.443	.33582	.492	[illegible]
.297	.19542	.346	.24117	.395	.28848	.444	.33682	.493	[illegible]
.298	.19634	.347	.24212	.396	.28945	.445	.33781	.494	[illegible]
.299	.19725	.348	.24307	.397	.29043	.446	.3388	.495	[illegible]
.3	.19817	.349	.24403	.398	.29141	.447	.3398	.496	[illegible]
.301	.19908	.35	.24498	.399	.29239	.448	.34079	.497	[illegible]
.302	.2	.351	.24593	.4	.29337	.449	.34179	.498	[illegible]
.303	.20092	.352	.24689	.401	.29435	.45	.34278	.499	[illegible]
.304	.20184	.353	.24784	.402	.29533	.451	.34378	.5	[illegible]

To Compute Area of a Segment of a Circle by prece Table.

Rule.—Divide height or versed sine by diameter of circle; find quot ..n *of versed sines.* Take area for versed sine opposite to it in ne right hand, multiply it by square of diameter, and it will gi

—Required area of a segment of a circle, its height being 10 feet and 'circle 50.

o = .2, and .2, *per table*, = .111 82; then .111 82 × 50^2 = 279.55 *feet.*

Division of a Height by Base, Quotient has a Remainder after 'hird Place of Decimals, and great Accuracy is required.

·Take area for first three figures, subtract it from next following iply remainder by said fraction, add product to first area, and ive area for whole quotient.

—What is area of a segment of a circle, diameter of which is 10 feet, and 1.575?

ɔ = .1575; *tabular area* for .157 = .078 92, and for .158 = .079 65, *the dif-ɔeen which is* .000 73.

(.000 73 = .000 365.

.157 = .078 92
.0005 = .000 365

.079 285, *sum by which square of diameter 'o be multiplied;* and .079 285 × 10^2 = 7.9285 *feet.*

Areas of Zones of a Circle.

Diameter of a Circle = 1, *and divided into* 1000 *equal Parts.*

a.	H'ght.	Area.	H'ght.	Area.	H'ght.	Area.	H'ght.	Area.
	.035	.034 97	.069	.068 78	.103	.102 27	.137	.135 27
	.036	.035 97	.07	.069 77	.104	.103 25	.138	.136 23
	.037	.036 97	.071	.070 76	.105	.104 22	.139	.137 19
	.038	.037 96	.072	.071 75	.106	.105 2	.14	.138 15
	.039	.038 96	.073	.072 74	.107	.106 18	.141	.139 11
	.04	.039 96	.074	.073 73	.108	.107 15	.142	.140 07
	.041	.040 95	.075	.074 72	.109	.108 13	.143	.141 03
	.042	.041 95	.076	.075 5	.11	.109 11	.144	.141 98
	.043	.042 95	.077	.076 69	.111	.110 08	.145	.142 94
	.044	.043 94	.078	.077 68	.112	.111 06	.146	.143 9
	.045	.044 94	.079	.078 67	.113	.112 03	.147	.144 85
	.046	.045 93	.08	.079 66	.114	.113	.148	.145 81
	.047	.046 93	.081	.080 64	.115	.113 98	.149	.146 77
	.048	.047 93	.082	.081 63	.116	.114 95	.15	.147 72
	.049	.048 92	.083	.082 62	.117	.115 92	.151	.148 67
	.05	.049 92	.084	.083 6	.118	.116 9	.152	.149 62
	.051	.050 91	.085	.084 59	.119	.117 87	.153	.150 58
	.052	.051 9	.086	.085 57	.12	.118 84	.154	.151 53
	.053	.052 9	.087	.086 56	.121	.119 81	.155	.152 48
	.054	.053 89	.088	.087 54	.122	.120 78	.156	.15[illegible]
	.055	.054 89	.089	.088 53	.123	.121 75	.157	.1[illegible]
	.056	.055 88	.09	.089 51	.124	.122 72	.158	.1[illegible]
	.057	.056 88	.091	.090 5	.125	.123 69	.159	.1[illegible]
	.058	.057 87	.092	.091 48	.126	.124 69	.16	.1[illegible]
	.059	.058 86	.093	.092 46	.127	.125 62	.161	.15[illegible]
[illegible]	.06	.059 86	.094	.093 44	.128	.126 59	.162	.15[illegible]
[illegible]	.061	.060 85	.095	.094 43	.129	.127 55	.1[illegible]	
	.062	.061 84	.096	.095 4	.13	.128 52		
	.063	.062 83	.097	.096 39	.131	.129 49		
	.064	.063 82	.098	.097 37	.132	.130 45		
	.065	.064 82	.099	.098 35	.133	.131 41		
	[illegible]66	.065 8	.1	.099 33	.134	.132 38		
	[illegible]67	.066 8	.101	.100 31	.135	.133 34		
	[illegible]68	.067 8	.102	.101 29	.136	.134 3		

H'ght.	Area.	H'ght.	Area.	H'ght.	Area.	H'ght.	Area.	H'ght.	Area.
.171	.16761	.226	.21805	.281	.26541	.336	.30864	.391	.34632
.172	.16855	.227	.21894	.282	.26624	.337	.30938	.392	.34694
.173	.16948	.228	.21983	.283	.26706	.338	.31012	.393	.34756
.174	.17042	.229	.22072	.284	.26789	.339	.31085	.394	.34818
.175	.17136	.23	.22161	.285	.26871	.34	.31159	.395	.34879
.176	.1723	.231	.2225	.286	.26953	.341	.31232	.396	.3494
.177	.17323	.232	.22335	.287	.27035	.342	.31305	.397	.35001
.178	.17417	.233	.22427	.288	.27117	.343	.31378	.398	.35062
.179	.1751	.234	.22515	.289	.27199	.344	.3145	.399	.35122
.18	.17603	.235	.22604	.29	.2728	.345	.31523	.4	.35182
.181	.17697	.236	.22692	.291	.27362	.346	.31595	.401	.35242
.182	.1779	.237	.2278	.292	.27443	.347	.31667	.402	.35302
.183	.17883	.238	.22868	.293	.27524	.348	.31739	.403	.35361
.184	.17976	.239	.22956	.294	.27605	.349	.31811	.404	.3542
.185	.18069	.24	.23044	.295	.27686	.35	.31882	.405	.35479
.186	.18162	.241	.23131	.296	.27766	.351	.31954	.406	.35538
.187	.18254	.242	.23219	.297	.27847	.352	.32025	.407	.35596
.188	.18347	.243	.23306	.298	.27927	.353	.32096	.408	.35654
.189	.1844	.244	.23394	.299	.28007	.354	.32167	.409	.35711
.19	.18532	.245	.23481	.3	.28088	.355	.32237	.41	.35769
.191	.18625	.246	.23568	.301	.28167	.356	.32307	.411	.35826
.192	.18717	.247	.23655	.302	.28247	.357	.32377	.412	.35883
.193	.18809	.248	.23742	.303	.28327	.358	.32447	.413	.35939
.194	.18902	.249	.23829	.304	.28406	.359	.32517	.414	.35995
.195	.18994	.25	.23915	.305	.28486	.36	.32587	.415	.36051
.196	.19086	.251	.24002	.306	.28565	.361	.32656	.416	.36107
.197	.19178	.252	.24089	.307	.28644	.362	.32725	.417	.3616[illegible]
.198	.1927	.253	.24175	.308	.28723	.363	.32794	.418	.36217
.199	.19361	.254	.24261	.309	.28801	.364	.32862	.419	.3627[illegible]
.2	.19453	.255	.24347	.31	.2888	.365	.32931	.42	.36326
.201	.19545	.256	.24433	.311	.28958	.366	.32999	.421	.3638
.202	.19636	.257	.24519	.312	.29036	.367	.33067	.422	.36434
.203	.19728	.258	.24604	.313	.29115	.368	.33135	.423	.36488
.204	.19819	.259	.2469	.314	.29192	.369	.33203	.424	.36541
.205	.1991	.26	.24775	.315	.2927	.37	.3327	.425	.3659[illegible]
.206	.20001	261	.24861	.316	.29348	.371	.33337	.426	.366[illegible]
.207	.20092	.262	.24946	.317	.29425	.372	.33404	.427	.3669[illegible]
.208	.20183	.263	.25021	.318	.29502	.373	.33471	.428	.3675
[illegible]	.20274	.264	.25116	.319	.2958	.374	.33537	.429	.3680[illegible]
	.20365	.265	.25201	.32	.29656	.375	.33604	.43	.3685[illegible]
	.20456	.266	.25285	.321	.29733	.376	.3367	.431	.3690[illegible]
	.20546	.267	.2537	.322	.2981	.377	.33735	.432	.3695[illegible]
	20637	.268	.25455	.323	.29886	.378	.33801	.433	.3700[illegible]
	20727	.269	.25539	.324	.29962	.379	.33866	.434	.3705[illegible]
	[illegible]	.27	.25623	.325	.30039	.38	.33931	.435	.3710[illegible]
		[illegible]	.25707	.326	.30114	.381	.33996	.436	.3715[illegible]
			.25791	.327	.3019	.382	.34061	.437	.3720[illegible]
			[illegible]5875	.328	.30266	.383	.34125	.438	.3725
			[illegible]959	.329	.30341	.384	.3419	.439	.3729
			[illegible]043	.33	.30416	.385	.34253	.44	.3734
			[illegible]126	.331	.30491	.386	.34317	.441	.37[illegible]
			[illegible]209	.332	.30566	.387	.3438	.442	.37
				[illegible]	.30641	.388	.34444	.443	.37
					.30715	.389	.34507	.444	.37.
					.3079	.39	.34569	.445	.37.

Area.	H'ght.	Area.	H'ght.	Area.	H'ght.	Area.	H'ght.	Area.
.376 24	.457	.380 96	.468	.385 14	.479	.388 67	.49	.391 37
.376 69	.458	.381 37	.469	.385 49	.48	.388 95	.491	.391 56
.377 14	.459	.381 77	.47	.385 83	.481	.389 23	.492	.391 75
.377 58	.46	.382 16	.471	.386 17	.482	.389 5	.493	.391 92
.378 02	.461	.382 55	.472	.386 5	.483	.389 76	.494	.392 08
.378 45	.462	.382 94	.473	.386 83	.484	.390 01	.495	.392 23
.378 88	.463	.383 32	.474	.387 15	.485	.390 26	.496	.392 36
.379 31	.464	.383 69	.475	.387 47	.486	.390 5	.497	.392 48
.379 73	.465	.384 06	.476	.387 78	.487	.390 73	.498	.392 58
.380 14	.466	.384 43	.477	.388 08	.488	.390 95	.499	.392 66
.380 56	.467	.384 79	.478	.388 38	.489	.391 17	.5	.392 7

...is Table is computed only for Zones, longest Chord of which is Diam-

...o Compute Area of a Zone by preceding Table.

When Zone is Less than a Semicircle.

...LE.—Divide height by diameter, find quotient in column of heights. ...area for height opposite to it in next column on right hand, multiply ...square of diameter, and product will give area of zone.

...MPLE.—Required area of a Zone, diameter of which is 50, and its height 15.

$15 \div 50 = .3$; and .3, *as per table*, $= .280\,88$.

...e $.280\,88 \times 50^2 = 702.2$ *area.*

When Zone is Greater than a Semicircle.

...E.—Take height on each side of diameter of circle, and ascertain, by ...ing Rule, their respective areas; add areas of these two portions to... and sum will give area.

...PLE.—Required area of a zone, diameter of circle being 50, and heights of each side of diameter of circle 20 and 15.

$20 \div 50 = .4$; .4, *as per table*, $= .351\,82$; and $.351\,82 \times 50^2 = 879.55$.
$15 \div 50 = .3$; .3, *as per table*, $= .280\,88$; and $.280\,88 \times 50^2 = 702.2$.

...$879.55 + 702.2 = 1581.75$ *area.*

...n Division of a Height by Chord, Quotient has a Remainder after Third Place of Decimals, and great Accuracy is required.

...—Take area for first three figures, subtract it from the next follow-..., multiply remainder by said fraction, and add product to first area; ...give area for whole quotient.

...E.—What is area of a zone of a circle, greater chord being 100 feet, ... 14 feet 3 ins.?

3 ins. $= 14.25$, and $14.25 \div 100 = .1425$; *tabular length for* $.142 = .14...$ $.143 = .141\,03$, *difference between which is* $.000\,96$.

...$\times .000\,96 = .000\,48$. Hence $.142 = .140\,07$
$.0005 = .000\,48$

$.140\,55$, ... *of area.*

...be multiplied; *and* $.140\,55 \times 100^2 = 1405.5$ ...

Squares, Cubes, and Square and Cube Roo

From 1 *to* 1600.

NUMBER.	SQUARE.	CUBE.	SQUARE ROOT.	CUBE R
1	1	1	1	1
2	4	8	1.414 2136	1.259
3	9	27	1.732 0508	1.442
4	16	64	2	1.587
5	25	125	2.236 068	1.709
6	36	216	2.449 4897	1.817
7	49	343	2.645 7513	1.912
8	64	512	2.828 4271	2
9	81	729	3	2.080
10	1 00	1 000	3.162 2777	2.154
11	1 21	1 331	3.316 6248	2.223
12	1 44	1 728	3.464 1016	2.289
13	1 69	2 197	3.605 5513	2.351
14	1 96	2 744	3.741 6574	2.410
15	2 25	3 375	3.872 9833	2.466
16	2 56	4 096	4	2.519
17	2 89	4 913	4.123 1056	2.571
18	3 24	5 832	4.242 6407	2.620
19	3 61	6 859	4.358 5989	2.668
20	4 00	8 000	4.472 136	2.714
21	4 41	9 261	4.582 5757	2.758
22	4 84	10 648	4.690 4158	2.802
23	5 29	12 167	4.795 8315	2.843
24	5 76	13 824	4.898 9795	2.884
25	6 25	15 625	5	2.924
26	6 76	17 576	5.099 0195	2.962
27	7 29	19 683	5.196 1524	3
28	7 84	21 952	5.291 5026	3.036
29	8 41	24 389	5.385 1648	3.072
30	9 00	27 000	5.477 2256	3.107
31	9 61	29 791	5.567 7644	3.141
32	10 24	32 768	5.656 8542	3.174
33	10 89	35 937	5.744 5626	3.207
34	11 56	39 304	5.830 9519	3.239
35	12 25	42 875	5.916 0798	3.271
36	12 96	46 656	6	3.301
37	13 69	50 653	6.082 7625	3.332
38	14 44	54 872	6.164 414	3.361
39	15 21	59 319	6.244 998	3.391
40	16 00	64 000	6.324 5553	3.419
41	16 81	68 921	6.403 1242	3.448
42	17 64	74 088	6.480 7407	3.476
43	18 49	79 507	6.557 4385	3.503
44	19 36	85 184	6.633 2496	3.530
45	20 25	91 125	6.708 2039	3.556
46	21 16	97 336	6.782 33	3.583
47	22 09	103 823	6.855 6546	3.608
48	23 04	110 592	6.928 2032	3.634
49	24 01	117 649	7	3.659
50	25 00	125 000	7.071 0678	3.684
51	26 01	132 651	7.141 4284	3.708
52	27 04	140 608	7.211 1026	3.732
53	28 09	148 877	7.280 1099	3.756
	29 16	157 464	7.348 4692	3.77

Square.	Cube.	Square Root.	Cube Root.
30 25	166 375	7.416 198 5	3.802 952 5
31 36	175 616	7.483 314 8	3.825 862 4
32 49	185 193	7.549 834 4	3.848 501 1
33 64	195 112	7.615 773 1	3.870 876 6
34 81	205 379	7.681 145 7	3.892 996 5
36 00	216 000	7.745 966 7	3.914 867 6
37 21	226 981	7.810 249 7	3.936 497 2
38 44	238 328	7.874 007 9	3.957 891 5
39 69	250 047	7.937 253 9	3.979 057 1
40 96	262 144	8	4
42 25	274 625	8.062 257 7	4.020 725 6
43 56	287 496	8.124 038 4	4.041 240 1
44 89	300 763	8.185 352 8	4.061 548
46 24	314 432	8.246 211 3	4.081 655 1
47 61	328 509	8.306 623 9	4.101 566 1
49 00	343 000	8.366 600 3	4.121 285 3
50 41	357 911	8.426 149 8	4.140 817 8
51 84	373 248	8.485 281 4	4.160 167 6
53 29	389 017	8.544 003 7	4.179 339
54 76	405 224	8.602 325 3	4.198 336 4
56 25	421 875	8.660 254	4.217 163 3
57 76	438 976	8.717 797 9	4.235 823 6
59 29	456 533	8.774 964 4	4.254 321
60 84	474 552	8.831 760 9	4.272 658 6
62 41	493 039	8.888 194 4	4.290 840 4
64 00	512 000	8.944 271 9	4.308 869 5
65 61	531 441	9	4.326 748 7
67 24	551 368	9.055 385 1	4.344 481 5
68 89	571 787	9.110 433 6	4.362 070 7
70 56	592 704	9.165 151 4	4.379 519 1
72 25	614 125	9.219 544 5	4.396 829 6
73 96	636 056	9.273 618 5	4.414 004 9
75 69	658 503	9.327 379 1	4.431 047 6
77 44	681 472	9.380 831 5	4.447 960 2
79 21	704 969	9.433 981 1	4.464 745 1
81 00	729 000	9.486 833	4.481 404 7
82 81	753 571	9.539 392	4.497 941 4
84 64	778 688	9.591 663	4.514 357 4
86 49	804 357	9.643 650 8	4.530 654 9
88 36	830 584	9.695 359 7	4.546 835 9
90 25	857 375	9.746 794 3	4.562 902 6
92 16	884 736	9.797 959	4.578 857
94 09	912 673	9.848 857 8	4.594 700 9
96 04	941 192	9.899 494 9	4.610 436 3
98 01	970 299	9.949 874 4	4.626 065
1 00 00	1 000 000	10	4.641 588 8
1 02 01	1 030 301	10.049 875 6	4.657 009 5
1 04 04	1 061 208	10.099 504 9	4.672 328 7
1 06 09	1 092 727	10.148 891 6	4.687 548 2
1 08 16	1 124 864	10.198 039	4.702 669 4
1 10 25	1 157 625	10.246 950 8	4.717 694
1 12 36	1 191 016	10.295 630 1	4.732 623 5
1 14 49	1 225 043	10.344 080 4	4.747 459 4
1 16 64	*1 259 712*	10.392 304 8	4.762 203 2
1 18 81	*1 295 029*	10.440 306 5	4.776 856 2
1 21 00	*1 331 000*	10.488 088 5	4.791 419 9

Squares, Cubes, and Square and Cube Ro

From 1 *to* 1600.

NUMBER.	SQUARE.	CUBE.	SQUARE ROOT.	CUBE R
1	1	1	1	1
2	4	8	1.414 213 6	1.25
3	9	27	1.732 050 8	1.44
4	16	64	2	1.58
5	25	125	2.236 068	1.70
6	36	216	2.449 489 7	1.81
7	49	343	2.645 751 3	1.91
8	64	512	2.828 427 1	2
9	81	729	3	2.08
10	1 00	1 000	3.162 277 7	2.15
11	1 21	1 331	3.316 624 8	2.22
12	1 44	1 728	3.464 101 6	2.28
13	1 69	2 197	3.605 551 3	2.35
14	1 96	2 744	3.741 657 4	2.41
15	2 25	3 375	3.872 983 3	2.46
16	2 56	4 096	4	2.51
17	2 89	4 913	4.123 105 6	2.57
18	3 24	5 832	4.242 640 7	2.62
19	3 61	6 859	4.358 598 9	2.66
20	4 00	8 000	4.472 136	2.71
21	4 41	9 261	4.582 575 7	2.75
22	4 84	10 648	4.690 415 8	2.80
23	5 29	12 167	4.795 831 5	2.84
24	5 76	13 824	4.898 979 5	2.88
25	6 25	15 625	5	2.92
26	6 76	17 576	5.099 019 5	2.96
27	7 29	19 683	5.196 152 4	3
28	7 84	21 952	5.291 502 6	3.03
29	8 41	24 389	5.385 164 8	3.07
30	9 00	27 000	5.477 225 6	3.10
31	9 61	29 791	5.567 764 4	3.14
32	10 24	32 768	5.656 854 2	3.17
33	10 89	35 937	5.744 562 6	3.20
34	11 56	39 304	5.830 951 9	3.23
35	12 25	42 875	5.916 079 8	3.27
36	12 96	46 656	6	3.30
37	13 69	50 653	6.082 762 5	3.33
38	14 44	54 872	6.164 414	3.36
39	15 21	59 319	6.244 998	3.39
40	16 00	64 000	6.324 555 3	3.41
41	16 81	68 921	6.403 124 2	3.44
	17 64	74 088	6.480 740 7	3.47
	18 49	79 507	6.557 438 5	3.50
	19 36	85 184	6.633 249 6	3.53
	20 25	91 125	6.708 203 9	3.55
	21 16	97 336	6.782 33	3.58
	[illegible]09	103 823	6.855 654 6	3.60
		110 592	6.928 203 2	3.63
		117 649	7	3.65
			7.071 067 8	3.68
			7.141 428 4	3.70
			7.211 102 6	3.73
			7.280 109 9	3.75
			7.348 469 2	3.7

Square.	Cube.	Square Root.	Cube Root.
30 25	166 375	7.416 198 5	3.802 952 5
31 36	175 616	7.483 314 8	3.825 862 4
32 49	185 193	7.549 834 4	3.848 501 1
33 64	195 112	7.615 773 1	3.870 876 6
34 81	205 379	7.681 145 7	3.892 996 5
36 00	216 000	7.745 966 7	3.914 867 6
37 21	226 981	7.810 249 7	3.936 497 2
38 44	238 328	7.874 007 9	3.957 891 5
39 69	250 047	7.937 253 9	3.979 057 1
40 96	262 144	8	4
42 25	274 625	8.062 257 7	4.020 725 6
43 56	287 496	8.124 038 4	4.041 240 1
44 89	300 763	8.185 352 8	4.061 548
46 24	314 432	8.246 211 3	4.081 655 1
47 61	328 509	8.306 623 9	4.101 566 1
49 00	343 000	8.366 600 3	4.121 285 3
50 41	357 911	8.426 149 8	4.140 817 8
51 84	373 248	8.485 281 4	4.160 167 6
53 29	389 017	8.544 003 7	4.179 339
54 76	405 224	8.602 325 3	4.198 336 4
56 25	421 875	8.660 254	4.217 163 3
57 76	438 976	8.717 797 9	4.235 823 6
59 29	456 533	8.774 964 4	4.254 321
60 84	474 552	8.831 760 9	4.272 658 6
62 41	493 039	8.888 194 4	4.290 840 4
64 00	512 000	8.944 271 9	4.308 869 5
65 61	531 441	9	4.326 748 7
67 24	551 368	9.055 385 1	4.344 481 5
68 89	571 787	9.110 433 6	4.362 070 7
70 56	592 704	9.165 151 4	4.379 519 1
72 25	614 125	9.219 544 5	4.396 829 6
73 96	636 056	9.273 618 5	4.414 004 9
75 69	658 503	9.327 379 1	4.431 047 6
77 44	681 472	9.380 831 5	4.447 960 2
79 21	704 969	9.433 981 1	4.464 745 1
81 00	729 000	9.486 833	4.481 404 7
82 81	753 571	9.539 392	4.497 941 4
84 64	778 688	9.591 663	4.514 357 4
86 49	804 357	9.643 650 8	4.530 654 9
88 36	830 584	9.695 359 7	4.546 835 9
90 25	857 375	9.746 794 3	4.562 902 6
92 16	884 736	9.797 959	4.578 857
94 09	912 673	9.848 857 8	4.594 700 9
96 04	941 192	9.899 494 9	4.610 436 3
98 01	970 299	9.949 874 4	4.626 065
1 00 00	1 000 000	10	4.641 588 8
1 02 01	1 030 301	10.049 875 6	4.657 009 5
1 04 04	1 061 208	10.099 504 9	4.672 328 7
1 06 09	1 092 727	10.148 891 6	4.68[illegible]
1 08 16	1 124 864	10.198 039	[illegible]
1 10 25	1 157 625	10.246 950 8	
1 12 36	1 191 016	10.295 630 1	
1 14 49	1 225 043	10.344 080 4	
1 16 64	1 259 712	10.392 304 8	
1 18 81	1 295 029	10.440 306 5	
1 21 00	1 331 000	10.488 088 5	

Number.	Square.	Cube.	Square Root.	Cu
111	1 23 21	1 367 631	10.535 653 8	4.
112	1 25 44	1 404 928	10.583 005 2	4.
113	1 27 69	1 442 897	10.630 145 8	4.
114	1 29 96	1 481 544	10.677 078 3	4.
115	1 32 25	1 520 875	10.723 805 3	4.
116	1 34 56	1 560 896	10.770 329 6	4.
117	1 36 89	1 601 613	10.816 653 8	4.
118	1 39 24	1 643 032	10.862 780 5	4.
119	1 41 61	1 685 159	10.908 712 1	4.
120	1 44 00	1 728 000	10.954 451 2	4.
121	1 46 41	1 771 561	11	4.
122	1 48 84	1 815 848	11.045 361	4.
123	1 51 29	1 860 867	11.090 536 5	4.
124	1 53 76	1 906 624	11.135 528 7	4.
125	1 56 25	1 953 125	11.180 339 9	5
126	1 58 76	2 000 376	11.224 972 2	5.
127	1 61 29	2 048 383	11.269 427 7	5.
128	1 63 84	2 097 152	11.313 708 5	5.
129	1 66 41	2 146 689	11.357 816 7	5.
130	1 69 00	2 197 000	11.401 754 3	5.
131	1 71 61	2 248 091	11.445 523 1	5.
132	1 74 24	2 299 968	11.489 125 3	5.
133	1 76 89	2 352 637	11.532 562 6	5.
134	1 79 56	2 406 104	11.575 836 9	5.
135	1 82 25	2 460 375	11.618 95	5.
136	1 84 96	2 515 456	11.661 903 8	5.
137	1 87 69	2 571 353	11.704 699 9	5.
138	1 90 44	2 628 072	11.747 340 1	5.
139	1 93 21	2 685 619	11.789 826 1	5.
140	1 96 00	2 744 000	11.832 159 6	5.
141	1 98 81	2 803 221	11.874 342 1	5.
142	2 01 64	2 863 288	11.916 375 3	5.
143	2 04 49	2 924 207	11.958 260 7	5.
144	2 07 36	2 985 984	12	5.
145	2 10 25	3 048 625	12.041 594 6	5.
146	2 13 16	3 112 136	12.083 046	5.
147	2 16 09	3 176 523	12.124 355 7	5.
148	2 19 04	3 241 792	12.165 525 1	5.
149	2 22 01	3 307 949	12.206 555 6	5.
150	2 25 00	3 375 000	12.247 448 7	5.
151	2 28 01	3 442 951	12.288 205 7	5.
152	2 31 04	3 511 008	12.328 828	5.
153	2 34 09	3 581 577	12.369 316 9	5.
154	2 37 16	3 652 264	12.409 673 6	5.
155	2 40 25	3 723 875	12.449 899 6	5.
156	2 43 36	3 796 416	12.489 996	5.
157	2 46 49	3 869 893	12.529 964 1	5.
[illegible]	2 49 64	3 944 312	12.569 805 1	5.
	2 52 81	4 019 679	12.609 520 2	5.
	[illegible]6 00	4 096 000	12.649 110 6	5.
	21	4 173 281	12.688 577 5	5.
	4	4 251 528	12.727 922 1	5.
		4 330 747	12.767 145 3	5.
		4 410 944	12.806 248 5	5.
		4 492 125	12.845 232 6	5.
		4 574 296	12.884 098 7	5

Square.	Cube.	Square Root.	Cube Root.
27889	4 657 463	12.922 848	5.506 878 4
28224	4 741 632	12.961 481 4	5.517 848 4
28561	4 826 809	13	5.528 774 8
28900	4 913 000	13.038 404 8	5.539 658 3
29241	5 000 211	13.076 696 8	5.550 499 1
29584	5 088 448	13.114 877	5.561 297 8
29929	5 177 717	13.152 946 4	5.572 054 6
30276	5 268 024	13.190 906	5.582 770 2
30625	5 359 375	13.228 756 6	5.593 444 7
30976	5 451 776	13.266 499 2	5.604 078 7
31329	5 545 233	13.304 134 7	5.614 672 4
31684	5 639 752	13.341 664 1	5.625 226 3
32041	5 735 339	13.379 088 2	5.635 740 8
32400	5 832 000	13.416 407 9	5.646 216 2
32761	5 929 741	13.453 624	5.656 652 8
33124	6 028 568	13.490 737 6	5.667 051 1
33489	6 128 487	13.527 749 3	5.677 411 4
33856	6 229 504	13 564 66	5.687 734
34225	6 331 625	13.601 470 5	5.698 019 2
34596	6 434 856	13.638 181 7	5.708 267 5
34969	6 539 203	13.674 794 3	5.718 479 1
35344	6 644 672	13.711 309 2	5.728 654 3
35721	6 751 269	13.747 727 1	5.738 793 6
36100	6 859 000	13.784 048 8	5.748 897 1
36481	6 967 871	13.820 275	5.758 965 2
36864	7 077 888	13.856 406 5	5.768 998 2
37249	7 189 057	13.892 44	5.778 996 6
37636	7 301 384	13.928 388 3	5.788 960 4
38025	7 414 875	13.964 24	5.798 89
38416	7 529 536	14	5.808 785 7
38809	7 645 373	14.035 668 8	5.818 647 9
39204	7 762 392	14.071 247 3	5.828 476 7
39601	7 880 599	14.106 736	5.838 272 5
40000	8 000 000	14.142 135 6	5.848 035 5
40401	8 120 601	14.177 446 9	5.857 766
40804	8 242 408	14.212 670 4	5.867 464 3
41209	8 365 427	14.247 806 8	5.877 130 7
41616	8 489 664	14.282 856 9	5.886 765 3
42025	8 615 125	14.317 821 1	5.896 368 5
42436	8 741 816	14.352 700 1	5.905 940 6
42849	8 869 743	14.387 494 6	5.915 481 7
43264	8 998 912	14.422 205 1	5.924 992 1
43681	9 129 329	14.456 832 3	5.934 472 1
44100	9 261 000	14.491 376 7	5.943 922
44521	9 393 931	14.525 839	5.953 341 8
44944	9 528 128	14.560 219 8	5.962 732
45369	9 663 597	14.594 519 5	5.972 092 6
45796	9 800 344	14.628 738 8	5.981 424
46225	9 938 375	14.662 878 3	5.990 726 4
46656	10 077 696	14.696 938 5	6
47089	10 218 313	14.730 919 9	6.0[illegible]
47524	10 360 232	14.764 823 1	6.0[illegible]
47961	10 503 459	14.798 648 6	6.0[illegible]
48400	10 648 000	14.832 397	6.[illegible]
48841	10 793 861	14.866 068 7	6.[illegible]
49284	10 941 048	14.899 664 4	6.[illegible]

Number.	Square.	Cube.	Square Root.	Cube Root.
223	4 97 29	11 089 567	14.933 184 5	6.064 127
224	5 01 76	11 239 424	14.966 629 5	6.073 177 9
225	5 06 25	11 390 625	15	6.082 202
226	5 10 76	11 543 176	15.033 296 4	6.091 199 4
227	5 15 29	11 697 083	15.066 519 2	6.100 170 2
228	5 19 84	11 852 352	15.099 668 9	6.109 114 7
229	5 24 41	12 008 989	15.132 746	6.118 033 2
230	5 29 00	12 167 000	15.165 750 9	6.126 925 7
231	5 33 61	12 326 391	15.198 684 2	6.135 792 4
232	5 38 24	12 487 168	15.231 546 2	6.144 633 7
233	5 42 89	12 649 337	15.264 337 5	6.153 445 5
234	5 47 56	12 812 904	15.297 058 5	6.162 240 1
235	5 52 25	12 977 875	15.329 709 7	6.171 005 8
236	5 56 96	13 144 256	15.362 291 5	6.179 746 6
237	5 61 69	13 312 053	15.394 804 3	6.188 462 8
238	5 66 44	13 481 272	15.427 248 6	6.197 154 4
239	5 71 21	13 651 919	15.459 624 8	6.205 821 8
240	5 76 00	13 824 000	15.491 933 4	6.214 465
241	5 80 81	13 997 521	15.524 174 7	6.223 084 3
242	5 85 64	14 172 488	15.556 349 2	6.231 679 7
243	5 90 49	14 348 907	15.588 457 3	6.240 251 5
244	5 95 36	14 526 784	15.620 499 4	6.248 799 8
245	6 00 25	14 706 125	15.652 475 8	6.257 324 8
246	6 05 16	14 886 936	15.684 387 1	6.265 826 6
247	6 10 09	15 069 223	15.716 233 6	6.274 305 4
248	6 15 04	15 252 992	15.748 015 7	6.282 761 3
249	6 20 01	15 438 249	15.779 733 8	6.291 194 6
250	6 25 00	15 625 000	15.811 388 3	6.299 605 3
251	6 30 01	15 813 251	15.842 979 5	6.307 993 5
252	6 35 04	16 003 008	15.874 507 9	6.316 359 6
253	6 40 09	16 194 277	15.905 973 7	6.324 703 5
254	6 45 16	16 387 064	15.937 377 5	6.333 025 6
255	6 50 25	16 581 375	15.968 719 4	6.341 325 7
256	6 55 36	16 777 216	16	6.349 604 2
257	6 60 49	16 974 593	16.031 219 5	6.357 861 1
258	6 65 64	17 173 512	16.062 378 4	6.366 096 8
259	6 70 81	17 373 979	16.093 476 9	6.374 311 1
260	6 76 00	17 576 000	16.124 515 5	6.382 504 3
261	6 81 21	17 779 581	16.155 494 4	6.390 676 5
262	6 86 44	17 984 728	16.186 414 1	6.398 827 9
263	6 91 69	18 191 447	16.217 274 7	6.406 958 5
264	6 96 96	18 399 744	16.248 076 8	6.415 068 7
265	7 02 25	18 609 625	16.278 820 6	6.423 158 3
	7 07 56	18 821 096	16.309 506 4	6.431 227 6
	7 12 89	19 034 163	16.340 134 6	6.439 276 7
	7 18 24	19 248 832	16.370 705 5	6.447 305 7
	7 23 61	19 465 109	16.401 219 5	6.455 314 8
	7 29 00	19 683 000	16.431 676 7	6.463 304 1
	7 34 41	19 902 511	16.462 077 6	6.471 273 6
	7 39 84	20 123 648	16.492 422 5	6.479 223 6
	7 45 29	20 346 417	16.522 711 6	6.487 154 1
	7 50 76	20 570 824	16.552 945 4	6.495 065 3
	7 56 25	20 796 875	16.583 124	6.502 957 [illegible]
	7 61 76	21 024 576	16.613 247 7	6.510 83
	7 67 29	21 253 933	16.643 317	6.518 6839
	7 72 84	21 484 952	16.678 332	6.526 518

Square.	Cube.	Square Root.	Cube Root.
7 78 41	21 717 639	16.703 293 1	6.534 335 1
7 84 00	21 952 000	16.733 200 5	6.542 132 6
7 89 61	22 188 041	16.763 054 6	6.549 911 6
7 95 24	22 425 768	16.792 855 6	6.557 672 2
8 00 89	22 665 187	16.822 603 8	6.565 414 4
8 06 56	22 906 304	16.852 299 5	6.573 138 5
8 12 25	23 149 125	16.881 943	6.580 844 3
8 17 96	23 393 656	16.911 534 5	6.588 532 3
8 23 69	23 639 903	16.941 074 3	6.596 202 3
8 29 44	23 887 872	16.970 562 7	6.603 854 5
8 35 21	24 137 569	17	6.611 489
8 41 00	24 389 000	17.029 386 4	6.619 106
8 46 81	24 642 171	17.058 722 1	6.626 705 4
8 52 64	24 897 088	17.088 007 5	6.634 287 4
8 58 49	25 153 757	17.117 242 8	6.641 852 2
8 64 36	25 412 184	17.146 428 2	6.649 399 8
8 70 25	25 672 375	17.175 564	6.656 930 2
8 76 16	25 934 336	17.204 650 5	6.664 443 7
8 82 09	26 198 073	17.233 687 9	6.671 940 3
8 88 04	26 463 592	17.262 676 5	6.679 42
8 94 01	26 730 899	17.291 616 5	6.686 883 1
9 00 00	27 000 000	17.320 508 1	6.694 329 5
9 06 01	27 270 901	17.349 351 6	6.701 759 3
9 12 04	27 543 608	17.378 147 2	6.709 172 9
9 18 09	27 818 127	17.406 895 2	6.716 57
9 24 16	28 094 464	17.435 595 8	6.723 950 8
9 30 25	28 372 625	17.464 249 2	6.731 315 5
9 36 36	28 652 616	17.492 855 7	6.738 664 1
9 42 49	28 934 443	17.521 415 5	6.745 996 7
9 48 64	29 218 112	17.549 928 8	6.753 313 4
9 54 81	29 503 629	17.578 395 8	6.760 614 3
9 61 00	29 791 000	17.606 816 9	6.767 899 5
9 67 21	30 080 231	17.635 192 1	6.775 169
9 73 44	30 371 328	17.663 521 7	6.782 422 9
9 79 69	30 664 297	17.691 806	6.789 661 3
9 85 96	30 959 144	17.720 045 1	6.796 884 4
9 92 25	31 255 875	17.748 239 3	6.804 092 1
9 98 56	31 554 496	17.776 388 8	6.811 284 7
10 04 89	31 855 013	17.804 493 8	6.818 462
10 11 24	32 157 432	17.832 554 5	6.825 624 2
10 17 61	32 461 759	17.860 571 1	6.832 771 4
10 24 00	32 768 000	17.888 543 8	6.839 903 7
10 30 41	33 076 161	17.916 472 9	6.847 021 3
10 36 84	33 386 248	17.944 358 4	6.854 124
10 43 29	33 698 267	17.972 200 8	6.861 212
10 49 76	34 012 224	18	6.868 285 5
10 56 25	34 328 125	18.027 756 4	6.875 344 3
10 62 76	34 645 976	18.055 470 1	6.882 388 8
10 69 29	34 965 783	18.083 141 3	6.889 418 8
10 75 84	35 287 552	18.110 770 3	6.8[illegible]
10 82 41	35 611 289	18.138 357 1	6.9[illegible]
10 89 00	35 937 000	18.165 902 1	6.[illegible]
10 95 61	36 264 691	18.193 405 4	6.[illegible]
11 02 24	36 594 368	18.220 867 2	6.[illegible]
11 08 89	36 926 037	18.248 287 6	6.[illegible]
11 15 56	37 259 704	18.275 666 9	6.[illegible]

Number.	Square.	Cube.	Square Root.	Cube R
335	11 22 25	37 595 375	18.303 005 2	6.94
336	11 28 96	37 933 056	18.330 302 8	6.95
337	11 35 69	38 272 753	18.357 559 8	6.95
338	11 42 44	38 614 472	18.384 776 3	6.96
339	11 49 21	38 958 219	18.411 952 6	6.97
340	11 56 00	39 304 000	18.439 088 9	6.97
341	11 62 81	39 651 821	18.466 185 3	6.98
342	11 69 64	40 001 688	18.493 242	6.99
343	11 76 49	40 353 607	18.520 259 2	7
344	11 83 36	40 707 584	18.547 237	7.00
345	11 90 25	41 063 625	18.574 175 6	7.01
346	11 97 16	41 421 736	18.601 075 2	7.02
347	12 04 09	41 781 923	18.627 936	7.02
348	12 11 04	42 144 192	18.654 758 1	7.03
349	12 18 01	42 508 549	18.681 541 7	7.04
350	12 25 00	42 875 000	18.708 286 9	7.04
351	12 32 01	43 243 551	18.734 994	7.05
352	12 39 04	43 614 208	18.761 663	7.06
353	12 46 09	43 986 977	18.788 294 2	7.06
354	12 53 16	44 361 864	18.814 887 7	7.07
355	12 60 25	44 738 875	18.841 443 7	7.08
356	12 67 36	45 118 016	18.867 962 3	7.08
357	12 74 49	45 499 293	18.894 443 6	7.09
358	12 81 64	45 882 712	18.920 887 9	7.10
359	12 88 81	46 268 279	18.947 295 3	7.10
360	12 96 00	46 656 000	18.973 666	7.11
361	13 03 21	47 045 831	19	7.12
362	13 10 44	47 437 928	19.026 297 6	7.12
363	13 17 69	47 832 147	19.052 558 9	7.13
364	13 24 96	48 228 544	19.078 784	7.14
365	13 32 25	48 627 125	19.104 973 2	7.14
366	13 39 56	49 027 896	19.131 126 5	7.15
367	13 46 89	49 430 863	19.157 244 1	7.15
368	13 54 24	49 836 032	19.183 326 1	7.16
369	13 61 61	50 243 409	19.209 372 7	7.17
370	13 69 00	50 653 000	19.235 384 1	7.17
371	13 76 41	51 064 811	19.261 360 3	7.18
372	13 83 84	51 478 848	19.287 301 5	7.19
373	13 91 29	51 895 117	19.313 207 9	7.19
374	13 98 76	52 313 624	19.339 079 6	7.20
375	14 06 25	52 734 375	19.364 916 7	7.21
376	14 13 76	53 157 376	19.390 719 4	7.21
377	14 21 29	53 582 633	19.416 487 8	7.22
378	14 28 84	54 010 152	19.442 222 1	7.23
	14 36 41	54 439 939	19.467 922 3	7.23
	14 44 00	54 872 000	19.493 588 7	7.24
	14 51 61	55 306 341	19.519 221 3	7.24
	14 59 24	55 742 968	19.544 820 3	7.25
	14 66 89	56 181 887	19.570 385 8	7.26
	14 74 56	56 623 104	19.595 917 9	7.26
	82 25	57 066 625	19.621 416 9	7.27
	9 96	57 512 456	19.646 882 7	7.28
	7 69	57 960 603	19.672 315 6	7.2
	5 44	58 411 072	19.697 715 6	7.
	3 21	58 863 869	19.723 082 9	
	.1 00	59 319 000	19.748 417 7	

...ER.	Square.	Cube.	Square Root.	Cube Root.
1	15 28 81	59 776 471	19.773 719 9	7.312 382 8
2	15 36 64	60 236 288	19.798 989 9	7.318 611 4
3	15 44 49	60 698 457	19.824 227 6	7.324 829 5
4	15 52 36	61 162 984	19.849 433 2	7.331 036 9
5	15 60 25	61 629 875	19.874 606 9	7.337 233 9
6	15 68 16	62 099 136	19.899 748 7	7.343 420 5
7	15 76 09	62 570 773	19.924 858 8	7.349 596 6
8	15 84 04	63 044 792	19.949 937 3	7.355 762 4
9	15 92 01	63 521 199	19.974 984 4	7.361 917 8
0	16 00 00	64 000 000	20	7.368 063
1	16 08 01	64 481 201	20.024 984 4	7.374 197 9
2	16 16 04	64 964 808	20.049 937 7	7.380 322 7
3	16 24 09	65 450 827	20.074 859 9	7.386 437 3
4	16 32 16	65 939 264	20.099 751 2	7.392 541 8
5	16 40 25	66 430 125	20.124 611 8	7.398 636 3
6	16 48 36	66 923 416	20.149 441 7	7.404 720 6
7	16 56 49	67 419 143	20.174 241	7.410 795
8	16 64 64	67 917 312	20.199 009 9	7.416 859 5
9	16 72 81	68 417 929	20.223 748 4	7.422 914 2
0	16 81 00	68 921 000	20.248 456 7	7.428 958 9
1	16 89 21	69 426 531	20.273 134 9	7.434 993 8
2	16 97 44	69 934 528	20.297 783 1	7.441 018 9
3	17 05 69	70 444 997	20.322 401 4	7.447 034 2
4	17 13 96	70 957 944	20.346 989 9	7.453 039 9
5	17 22 25	71 473 375	20.371 548 8	7.459 035 9
6	17 30 56	71 991 296	20.396 078 1	7.465 022 3
7	17 38 89	72 511 713	20.420 577 9	7.470 999 1
8	17 47 24	73 034 632	20.445 048 3	7.476 966 4
9	17 55 61	73 560 059	20.469 489 5	7.482 924 2
0	17 64 00	74 088 000	20.493 901 5	7.488 872 4
1	17 72 41	74 618 461	20.518 284 5	7.494 811 3
2	17 80 84	75 151 448	20.542 638 6	7.500 740 6
3	17 89 29	75 686 967	20.566 963 8	7.506 660 7
4	17 97 76	76 225 024	20.591 260 3	7.512 571 5
5	18 06 25	76 765 625	20.615 528 1	7.518 473
6	18 14 76	77 308 776	20.639 767 4	7.524 365 2
7	18 23 29	77 854 483	20.663 978 3	7.530 248 2
8	18 31 84	78 402 752	20.688 160 9	7.536 122 1
9	18 40 41	78 953 589	20.712 315 2	7.541 986 7
0	18 49 00	79 507 000	20.736 441 4	7.547 842 3
1	18 57 61	80 062 991	20.760 539 5	7.553 688 8
2	18 66 24	80 621 568	20.784 609 7	7.559 526 3
3	18 74 89	81 182 737	20.808 652	7.565 354 8
4	18 83 56	81 746 504	20.832 666 7	7.571 174 3
5	18 92 25	82 312 875	20.856 653 6	7.576 984 9
6	19 00 96	82 881 856	20.880 613	7.582 786 5
7	19 09 69	83 453 453	20.904 545	7.588 579 3
8	19 18 44	84 027 672	20.928 449 5	7.594 363 3
9	19 27 21	84 604 519	20.952 326 8	7.600 138 5
0	19 36 00	85 184 000	20.976 177	7.605 001 0
1	19 44 81	85 766 121	21	7.6
2	19 53 64	86 350 888	21.023 796	7.[illegible]
3	19 62 49	86 938 307	21.047 565 2	7.
[illegible]	19 71 36	87 528 384	21.071 307 5	7
	19 80 25	88 121 125	21.095 023 1	[illegible]
	19 89 16	88 716 536	21.118 712 1	[illegible]

NUMBER.	SQUARE.	CUBE.	SQUARE ROOT.	CUBE RO
559	31 24 81	174 676 879	23.643 180 8	8.237
560	31 36 00	175 616 000	23.664 319 1	8.242
561	31 47 21	176 558 481	23.685 438 6	8.247
562	31 58 44	177 504 328	23.706 539 2	8.252
563	31 69 69	178 453 547	23.727 621	8.257
564	31 80 96	179 406 144	23.748 684 2	8.262
565	31 92 25	180 362 125	23.769 728 6	8.267
566	32 03 56	181 321 496	23.790 754 5	8.271
567	32 14 89	182 284 263	23.811 761 8	8.276
568	32 26 24	183 250 432	23.832 750 6	8.281
569	32 37 61	184 220 009	23.853 720 9	8.286
570	32 49 00	185 193 000	23.874 672 8	8.291
571	32 60 41	186 169 411	23.895 606 3	8.296
572	32 71 84	187 149 248	23.916 521 5	8.301
573	32 83 29	188 132 517	23.937 418 4	8.305
574	32 94 76	189 119 224	23.958 297 1	8.310
575	33 06 25	190 109 375	23.979 157 6	8.315
576	33 17 76	191 102 976	24	8.320
577	33 29 29	192 100 033	24.020 824 3	8.325
578	33 40 84	193 100 552	24.041 630 6	8.329
579	33 52 41	194 104 539	24.062 418 8	8.334
580	33 64 00	195 112 000	24.083 189 1	8.339
581	33 75 61	196 122 941	24.103 941 6	8.344
582	33 87 24	197 137 368	24.124 676 2	8.349
583	33 98 89	198 155 287	24.145 392 9	8.353
584	34 10 56	199 176 704	24.166 091 9	8.358
585	34 22 25	200 201 625	24.186 773 2	8.363
586	34 33 96	201 230 056	24.207 436 9	8.368
587	34 45 69	202 262 003	24.228 082 9	8.372
588	34 57 44	203 297 472	24.248 711 3	8.377
589	34 69 21	204 336 469	24.269 322 2	8.382
590	34 81 00	205 379 000	24.289 915 6	8.387
591	34 92 81	206 425 071	24.310 491 6	8.391
592	35 04 64	207 474 688	24.331 050 1	8.396
593	35 16 49	208 527 857	24.351 591 3	8.401
594	35 28 36	209 584 584	24.372 115 2	8.406
595	35 40 25	210 644 875	24.392 621 8	8.410
596	35 52 16	211 708 736	24.413 111 2	8.415
597	35 64 09	212 776 173	24.433 583 4	8.420
598	35 76 04	213 847 192	24.454 038 5	8.424
599	35 88 01	214 921 799	24.474 476 5	8.429
600	36 00 00	216 000 000	24.494 897 4	8.434
601	36 12 01	217 081 801	24.515 301 3	8.439
602	36 24 04	218 167 208	24.535 688 3	8.443
603	36 36 09	219 256 227	24.556 058 3	8.448
604	36 48 16	220 348 864	24.576 411 5	8.453
605	36 60 25	221 445 125	24.596 747 8	8.457
606	36 72 36	222 545 016	24.617 067 3	8.462
497	36 84 49	223 648 543	24.637 37	8.467
458	36 96 64	224 755 712	24.657 656	8.471
409	37 08 81	225 866 529	24.677 925 4	8.476
610	37 21 00	226 981 000	24.698 178 1	8.480
611	37 33 21	228 099 131	24.718 414 2	8.485
612	37 45 44	229 220 928	24.738 633 8	8.490
613	37 57 69	230 346 397	24.758 836 8	8.49
614	37 69 96	231 475 544	24.779 023 4	8.4

Square.	Cube.	Square Root.	Cube Root.
25 30 09	127 263 527	22.427 661 5	7.952 847 7
25 40 16	128 024 064	22.449 944 3	7.958 114 4
25 50 25	128 787 625	22.472 205 1	7.963 374 3
25 60 36	129 554 216	22.494 443 8	7.968 627 1
25 70 49	130 323 843	22.516 660 5	7.973 873 1
25 80 64	131 096 512	22.538 855 3	7.979 112 2
25 90 81	131 872 229	22.561 028 3	7.984 344 4
26 01 00	132 651 000	22.583 179 6	7.989 569 7
26 11 21	133 432 831	22.605 309 1	7.994 788 3
26 21 44	134 217 728	22.627 417	8
26 31 69	135 005 697	22.649 503 3	8.005 204 9
26 41 96	135 796 744	22.671 568 1	8.010 403 2
26 52 25	136 590 875	22.693 611 4	8.015 594 6
26 62 56	137 388 096	22.715 633 4	8.020 779 4
26 72 89	138 188 413	22.737 634	8.025 957 4
26 83 24	138 991 832	22.759 613 4	8.031 128 7
26 93 61	139 798 359	22.781 571 5	8.036 293 5
27 04 00	140 608 000	22.803 508 5	8.041 451 5
27 14 41	141 420 761	22.825 424 4	8.046 603
27 24 84	142 236 648	22.847 319 3	8.051 747 9
27 35 29	143 055 667	22.869 193 3	8.056 886 2
27 45 76	143 877 824	22.891 046 3	8.062 018
27 56 25	144 703 125	22.912 878 5	8.067 143 2
27 66 76	145 531 576	22.934 689 9	8.072 262
27 77 29	146 363 183	22.956 480 6	8.077 374 3
27 87 84	147 197 952	22.978 250 6	8.082 48
27 98 41	148 035 889	23	8.087 579 4
28 09 00	148 877 000	23.021 728 9	8.092 672 3
28 19 61	149 721 291	23.043 437 2	8.097 758 9
28 30 24	150 568 768	23.065 125 2	8.102 839
28 40 89	151 419 437	23.086 792 8	8.107 912 8
28 51 56	152 273 304	23.108 44	8.112 980 3
28 62 25	153 130 375	23.130 067	8.118 041 4
28 72 96	153 990 656	23.151 673 8	8.123 096 2
28 83 69	154 854 153	23.173 260 5	8.128 144 7
28 94 44	155 720 872	23.194 827	8.133 187
29 05 21	156 590 819	23.216 373 5	8.138 223
29 16 00	157 464 000	23.237 900 1	8.143 252 9
29 26 81	158 340 421	23.259 406 7	8.148 276 5
29 37 64	159 220 088	23.280 893 5	8.153 293 9
29 48 49	160 103 007	23.302 360 4	8.158 305 1
29 59 36	160 989 184	23.323 807 6	8.163 310 2
29 70 25	161 878 625	23.345 235 1	8.168 309 2
29 81 16	162 771 336	23.366 642 9	8.173 302
29 92 09	163 667 323	23.388 031 1	8.178 288 8
30 03 04	164 566 592	23.409 399 8	8.183 269 5
30 14 01	165 469 149	23.430 749	[illegible]
30 25 00	166 375 000	23.452 078 8	[illegible] 212 7
30 36 01	167 284 151	23.473 389 2	[illegible]
30 47 04	168 196 608	23.494 680 2	[illegible]
30 58 09	169 112 377	23.515 952	[illegible]
30 69 16	170 031 464	23.537 204	[illegible] 027 1
30 80 25	170 953 875	23 558 43	[illegible] 65 7
30 91 36	171 879 616	23.579 65	
31 02 49	172 808 693	23.600 8	
31 13 64	173 741 112	23.622 0	

A A*

Number.	Square.	Cube.	Square Root.	Cube
559	31 24 81	174 676 879	23.643 180 8	8.23
560	31 36 00	175 616 000	23.664 319 1	8.24
561	31 47 21	176 558 481	23.685 438 6	8.24
562	31 58 44	177 504 328	23.706 539 2	8.25
563	31 69 69	178 453 547	23.727 621	8.25
564	31 80 96	179 406 144	23.748 684 2	8.26
565	31 92 25	180 362 125	23.769 728 6	8.26
566	32 03 56	181 321 496	23.790 754 5	8.27
567	32 14 89	182 284 263	23.811 761 8	8.27
568	32 26 24	183 250 432	23.832 750 6	8.28
569	32 37 61	184 220 009	23.853 720 9	8.28
570	32 49 00	185 193 000	23.874 672 8	8.29
571	32 60 41	186 169 411	23.895 606 3	8.29
572	32 71 84	187 149 248	23.916 521 5	8.30
573	32 83 29	188 132 517	23.937 418 4	8.30
574	32 94 76	189 119 224	23.958 297 1	8.31
575	33 06 25	190 109 375	23.979 157 6	8.31
576	33 17 76	191 102 976	24	8.32
577	33 29 29	192 100 033	24.020 824 3	8.32
578	33 40 84	193 100 552	24.041 630 6	8.32
579	33 52 41	194 104 539	24.062 418 8	8.33
580	33 64 00	195 112 000	24.083 189 1	8.33
581	33 75 61	196 122 941	24.103 941 6	8.34
582	33 87 24	197 137 368	24.124 676 2	8.34
583	33 98 89	198 155 287	24.145 392 9	8.35
584	34 10 56	199 176 704	24.166 091 9	8.35
585	34 22 25	200 201 625	24.186 773 2	8.36
586	34 33 96	201 230 056	24.207 436 9	8.36
587	34 45 69	202 262 003	24.228 082 9	8.37
588	34 57 44	203 297 472	24.248 711 3	8.37
589	34 69 21	204 336 469	24.269 322 2	8.38
590	34 81 00	205 379 000	24.289 915 6	8.38
591	34 92 81	206 425 071	24.310 491 6	8.39
592	35 04 64	207 474 688	24.331 050 1	8.39
593	35 16 49	208 527 857	24.351 591 3	8.40
594	35 28 36	209 584 584	24.372 115 2	8.40
595	35 40 25	210 644 875	24.392 621 8	8.41
596	35 52 16	211 708 736	24.413 111 2	8.41
597	35 64 09	212 776 173	24.433 583 4	8.42
598	35 76 04	213 847 192	24.454 038 5	8.42
599	35 88 01	214 921 799	24.474 476 5	8.42
600	36 00 00	216 000 000	24.494 897 4	8.43
601	36 12 01	217 081 801	24.515 301 3	8.43
602	36 24 04	218 167 208	24.535 688 3	8.44
603	36 36 09	219 256 227	24.556 058 3	8.44
604	36 48 16	220 348 864	24.576 411 5	8.45
605	36 60 25	221 445 125	24.596 747 8	8.45
606	36 72 36	222 545 016	24.617 067 3	8.46
607	36 84 49	223 648 543	24.637 37	8.46
608		224 755 712	24.657 656	8.47
609		225 866 529	24.677 925 4	8.47
610		226 981 000	24.698 178 1	8.48
		228 099 131	24.718 414 2	8.48
		229 220 928	24.738 633 8	8.49
		230 346 397	24.758 836 8	8.49
		231 475 544	24.779 023 4	8.4

ber.	Square.	Cube.	Square Root.	Cube Root.
5	37 82 25	232 608 375	24.799 193 5	8.504 035
16	37 94 56	233 744 896	24.819 347 3	8.508 641 7
7	38 06 89	234 885 113	24.839 484 7	8.513 243 5
8	38 19 24	236 029 032	24.859 605 8	8.517 840 3
9	38 31 61	237 176 659	24.879 710 6	8.522 432 1
10	38 44 00	238 328 000	24.899 799 2	8.527 018 9
11	38 56 41	239 483 061	24.919 871 6	8.531 600 9
12	38 68 84	240 641 848	24.939 927 8	8.536 178
13	38 81 29	241 804 367	24.959 967 9	8.540 750 1
14	38 93 76	242 970 624	24.979 992	8.545 317 3
5	39 06 25	244 140 625	25	8.549 879 7
6	39 18 76	245 134 376	25.019 992	8.554 437 2
7	39 31 29	246 491 883	25.039 968 1	8.558 989 9
8	39 43 84	247 673 152	25.059 928 2	8.563 537 7
9	39 56 41	248 858 189	25.079 872 4	8.568 080 7
0	39 69 00	250 047 000	25.099 800 8	8.572 618 9
1	39 81 61	251 239 591	25.119 713 4	8.577 152 3
2	39 94 24	252 435 968	25.139 610 2	8.581 680 9
3	40 06 89	253 636 137	25.159 491 3	8.586 204 7
4	40 19 56	254 840 104	25.179 356 6	8.590 723 8
5	40 32 25	256 047 875	25.199 206 3	8.595 238
6	40 44 96	257 259 456	25.219 040 4	8.599 747 6
7	40 57 69	258 474 853	25.238 858 9	8.604 252 5
8	40 70 44	259 694 072	25.258 661 9	8.608 752 6
9	40 83 21	260 917 119	25.278 449 3	8.613 248
0	40 96 00	262 144 000	25.298 221 3	8.617 738 8
1	41 08 81	263 374 721	25.317 977 8	8.622 224 8
2	41 21 64	264 609 288	25.337 718 9	8.626 706 3
3	41 34 49	265 847 707	25.357 444 7	8.631 183
4	41 47 36	267 089 984	25.377 155 1	8.635 655 1
5	41 60 25	268 336 125	25.396 850 2	8.640 122 6
6	41 73 16	269 585 136	25.416 530 1	8.644 585 5
7	41 86 09	270 840 023	25.436 194 7	8.649 043 7
8	41 99 04	272 097 792	25.455 844 1	8.653 497 4
9	42 12 01	273 359 549	25.475 478 4	8.657 946 5
0	42 25 00	274 625 000	25.495 097 6	8.662 391 1
1	42 38 01	275 894 451	25.514 701 6	8.666 831
2	42 51 04	277 167 808	25.534 290 7	8.671 266 5
3	42 64 09	278 445 077	25 553 864 7	8.675 697 4
4	42 77 16	279 726 264	25.573 423 7	8.680 123 7
5	42 90 25	281 011 375	25.592 967 8	8.684 545 6
6	43 03 36	282 300 416	25.612 496 9	8.688 963
7	43 16 49	283 593 393	25.632 011 2	8.693 375 9
8	43 29 64	284 890 312	25.651 510 7	8.697 784 3
9	43 42 81	286 191 179	25.670 995 3	8.702 188 2
0	43 56 00	287 496 000	25.690 465 2	8.706 587 7
1	43 69 21	288 804 781	25.709 920 3	8.710 982 7
2	43 82 44	290 117 528	25.729 360 7	8.715 373 4
3	43 95 69	291 434 247	25.748 786 4	8.719 759 6
4	44 08 96	292 754 944	25.768 197 5	8.724 141 …
5	44 22 25	294 079 625	25.787 593 9	8.728 51…
6	44 35 56	295 408 296	25.806 975 8	8.732 8…
7	44 48 89	296 740 963	25.826 343 1	8.737 2…
8	44 62 24	298 077 632	25.845 696	8.741 6…
9	44 75 61	299 418 309	25.865 034 3	8.745…
0	44 89 00	300 763 000	25.884 358 2	8.750…

Number.	Square.	Cube.	Square Root.	Cube R
783	61 30 89	480 048 687	27.982 137 2	9.216
784	61 46 56	481 890 304	28	9.220
785	61 62 25	483 736 625	28.017 851 5	9.224
786	61 77 96	485 587 656	28.035 691 5	9.228
787	61 93 69	487 443 403	28.053 520 3	9.232
788	62 09 44	489 303 872	28.071 337 7	9.236
789	62 25 21	491 169 069	28.089 143 8	9.240
790	62 41 00	493 039 000	28.106 938 6	9.244
791	62 56 81	494 913 671	28.124 722 2	9.248
792	62 72 64	496 793 088	28.142 494 6	9.252
793	62 88 49	498 677 257	28.160 255 7	9.256
794	63 04 36	500 566 184	28.178 005 6	9.259
795	63 20 25	502 459 875	28.195 744 4	9.263
796	63 36.16	504 358 336	28.213 472	9.267
797	63 52 09	506 261 573	28.231 188 4	9.271
798	63 68 04	508 169 592	28.248 893 8	9.275
799	63 84 01	510 082 399	28.266 588 1	9.279
800	64 00 00	512 000 000	28.284 271 2	9.283
801	64 16 01	513 922 401	28.301 943 4	9.287
802	64 32 04	515 849 608	28.319 604 5	9.290
803	64 48 09	517 781 627	28.337 254 6	9.294
804	64 64 16	519 718 464	28.354 893 8	9.298
805	64 80 25	521 660 125	28.372 521 9	9.302
806	64 96 36	523 606 616	28.390 139 1	9.306
807	65 12 49	525 557 943	28.407 745 4	9.310
808	65 28 64	527 514 112	28.425 340 8	9.314
809	65 44 81	529 475 129	28.442 925 3	9.317
810	65 61 00	531 441 000	28.460 498 9	9.321
811	65 77 21	533 411 731	28.478 061 7	9.325
812	65 93 44	535 387 328	28.495 613 7	9.329
813	66 09 69	537 367 797	28.513 154 9	9.333
814	66 25 96	539 353 144	28.530 685 2	9.337
815	66 42 25	541 343 375	28.548 204 8	9.340
816	66 58 56	543 338 496	28.565 713 7	9.344
817	66 74 89	545 338 513	28.583 211 9	9.348
818	66 91 24	547 343 432	28.600 699 3	9.352
819	67 07 61	549 353 259	28.618 176	9.356
820	67 24 00	551 368 000	28.635 642 1	9.359
821	67 40 41	553 387 661	28.653 097 6	9.363
822	67 56 84	555 412 248	28.670 542 4	9.367
823	67 73 29	557 441 767	28.687 976 6	9.371
824	67 89 76	559 476 224	28.705 400 2	9.375
825	68 06 25	561 515 625	28.722 813 2	9.378
826	68 22 76	563 559 976	28.740 215 7	9.382
827	68 39 29	565 609 283	28.757 607 7	9.386
828	68 55 84	567 663 552	28.774 989 1	9.390
829	68 72 41	569 722 789	28.792 360 1	9.394
830	68 89 00	571 787 000	28.809 720 6	9.397
831	69 05 61	573 856 191	28.827 070 6	9.401
832	69 22 24	575 930 368	28.844 410 2	9.405
833	69 38 89	578 009 537	28.861 739 4	9.409
834	69 55 56	580 093 704	28.879 058 2	9.412
[illegible]	69 72 25	582 182 875	28.896 366 6	9.41
[illegible]	69 88 96	584 277 056	28.913 664 6	9.4
[illegible]	70 05 69	586 376 253	28.930 952 3	9.
[illegible]	70 22 44	588 480 472	28.948 229 7	[illegible]

Square.	Cube.	Square Root.	Cube Root.
70 39 21	590 589 719	28.965 496 7	9.431 642 3
70 56 00	592 704 000	28.982 753 5	9.435 38
70 72 81	.594 823 321	29	9.439 130 7
70 89 64	596 947 688	29.017 236 3	9.442 870 4
71 06 49	599 077 107	29.034 462 3	9.446 607 2
71 23 36	601 211 584	29.051 678 1	9.450 341
71 40 25	603 351 125	29.068 883 7	9.454 071 9
71 57 16	605 495 736	29.086 079 1	9.457 799 9
71 74 09	607 645 423	29.103 264 4	9.461 524 9
71 91 04	609 800 192	29.120 439 6	9.465 247
72 08 01	611 960 049	29.137 604 6	9.468 966 1
72 25 00	614 125 000	29.154 759 5	9.472 682 4
72 42 01	616 295 051	29.171 904 3	9.476 395 7
72 59 04	618 470 208	29.189 039	9.480 106 1
72 76 09	620 650 477	29.206 163 7	9.483 813 6
72 93 16	622 835 864	29.223 278 4	9.487 518 2
73 10 25	625 026 375	29.240 383	9.491 22
73 27 36	627 222 016	29.257 477 7	9.494 918 8
73 44 49	629 422 793	29.274 562 3	9.498 614 7
73 61 64	631 628 712	29.291 637	9.502 307 8
73 78 81	633 839 779	29.308 701 8	9.505 998
73 96 00	636 056 000	29.325 756 6	9.509 685 4
74 13 21	638 277 381	29.342 801 5	9.513 369 9
74 30 44	640 503 928	29.359 836 5	9.517 051 5
74 47 69	642 735 647	29.376 861 6	9.520 730 3
74 64 96	644 972 544	29.393 876 9	9.524 406 3
74 82 25	647 214 625	29.410 882 3	9.528 079 4
74 99 56	649 461 896	29.427 877 9	9.531 749 7
75 16 89	651 714 363	29.444 863 7	9.535 417 2
75 34 24	653 972 032	29.461 839 7	9.539 081 8
75 51 61	656 234 909	29.478 805 9	9.542 743 7
75 69 00	658 503 000	29.495 762 4	9.546 402 7
75 86 41	660 776 311	29.512 709 1	9.550 058 9
76 03 84	663 054 848	29.529 646 1	9.553 712 3
76 21 29	665 338 617	29.546 573 4	9.557 363
76 38 76	667 627 624	29.563 491	9.561 010 8
76 56 25	669 921 875	29.580 398 9	9.564 655 9
76 73 76	672 221 376	29.597 297 2	9.568 298 2
76 91 29	674 526 133	29.614 185 8	9.571 937 7
77 08 84	676 836 152	29.631 064 8	9.575 574 5
77 26 41	679 151 439	29.647 934 2	9.579 208 5
77 44 00	681 472 000	29.664 793 9	9.582 839 7
77 61 61	683 797 841	29.681 644 2	9.586 468 2
77 79 24	686 128 968	29.698 484 8	9.590 093 7
77 96 89	688 465 387	29.715 315 9	9.593 716 9
78 14 56	690 807 104	29.732 137 5	9.597 337 3
78 32 25	693 154 125	29.748 949 6	9.600 954 8
78 49 96	695 506 456	29.765 752 1	0.604 569 6
78 67 69	697 864 103	29.782 545 2	181 7
78 85 44	700 227 072	29.799 328 9	1
79 03 21	702 595 369	29.816 103	
79 21 00	704 969 000	29.832 867 8	
79 38 81	707 347 971	29.849 623 1	
79 56 64	709 732 288	29.866 369	
79 74 49	712 121 957	29.883 105 6	
79 92 36	714 516 984	29.899 832 8	

Number.	Square.	Cube.	Square Root.	Cube R
895	80 10 25	716 917 375	29.916 550 6	9.636
896	80 28 16	719 323 136	29.933 259 1	9.640
897	80 46 09	721 734 273	29.949 958 3	9.644
898	80 64 04	724 150 792	29.966 648 1	9.647
899	80 82 01	726 572 699	29.983 328 7	9.651
900	81 00 00	729 000 000	30	9.654
901	81 18 01	731 432 701	30.016 662	9.658
902	81 36 04	733 870 808	30.033 314 8	9.662
903	81 54 09	736 314 327	30.049 958 4	9.665
904	81 72 16	738 763 264	30.066 592 8	9.669
905	81 90 25	741 217 625	30.083 217 9	9.672
906	82 08 36	743 677 416	30.099 833 9	9.676
907	82 26 49	746 142 643	30.116 440 7	9.679
908	82 44 64	748 613 312	30.133 038 3	9.683
909	82 62 81	751 089 429	30.149 626 9	9.686
910	82 81 00	753 571 000	30.166 206 3	9.690
911	82 99 21	756 058 031	30.182 776 5	9.694
912	83 17 44	758 550 528	30.199 337 7	9.697
913	83 35 69	761 048 497	30.215 889 9	9.701
914	83 53 96	763 551 944	30.232 432 9	9.704
915	83 72 25	766 060 875	30.248 966 9	9.708
916	83 90 56	768 575 296	30.265 491 9	9.711
917	84 08 89	771 095 213	30.282 007 9	9.715
918	84 27 24	773 620 632	30.298 514 8	9.718
919	84 45 61	776 151 559	30.315 012 8	9.722
920	84 64 00	778 688 000	30.331 501 8	9.725
921	84 82 41	781 229 961	30.347 981 8	9.729
922	85 00 84	783 777 448	30.364 452 9	9.732
923	85 19 29	786 330 467	30.380 915 1	9.736
924	85 37 76	788 889 024	30.397 368 3	9.739
925	85 56 25	791 453 125	30.413 812 7	9.743
926	85 74 76	794 022 776	30.430 248 1	9.746
927	85 93 29	796 597 983	30.446 674 7	9.750
928	86 11 84	799 178 752	30.463 092 4	9.753
929	86 30 41	801 765 089	30.479 501 3	9.757
930	86 49 00	804 357 000	30.495 901 4	9.761
931	86 67 61	806 954 491	30.512 292 6	9.764
932	86 86 24	809 557 568	30.528 675	9.767
933	87 04 89	812 166 237	30.545 048 7	9.771
934	87 23 56	814 780 504	30.561 413 6	9.774
935	87 42 25	817 400 375	30.577 769 7	9.778
936	87 60 96	820 025 856	30.594 117 1	9.781
937	87 79 69	822 656 953	30.610 455 7	9.785
938	87 98 44	825 293 672	30.626 785 7	9.788
939	88 17 21	827 936 019	30.643 106 9	9.792
940	88 36 00	830 584 000	30.659 419 4	9.795
941	88 54 81	833 237 621	30.675 723 3	9.799
942	88 73 64	835 896 888	30.692 018 5	9.802
943	88 92 49	838 561 807	30.708 305 1	9.806
	89 11 36	841 232 384	30.724 583	9.809
	89 30 25	843 908 625	30.740 852 3	9.813
	49 16	846 590 536	30.757 113	9.816
	09	849 278 123	30.773 365 1	9.82
	04	851 971 392	30.789 608 6	9.8
	01	854 670 349	30.805 843 6	9.
		857 375 000	30.822 07	

Square.	Cube.	Square Root.	Cube Root.
90 44 01	860 085 351	30.838 287 9	9.833 923 8
90 63 04	862 801 408	30.854 497 2	9.837 369 5
90 82 09	865 523 177	30.870 698 1	9.840 812 7
91 01 16	868 250 664	30.886 890 4	9.844 253 6
91 20 25	870 983 875	30.903 074 3	9.847 692
91 39 36	873 722 816	30.919 247 7	9.851 128
91 58 49	876 467 493	30.935 416 6	9.854 561 7
91 77 64	879 217 912	30.951 575 1	9.857 992 9
91 96 81	881 974 079	30.967 725 1	9.861 421 8
92 16 00	884 736 000	30.983 866 8	9.864 848 3
92 35 21	887 503 681	31	9.868 272 4
92 54 44	890 277 128	31.016 124 8	9.871 694 1
92 73 69	893 056 347	31.032 241 3	9.875 113 5
92 92 96	895 841 344	31.048 349 4	9.878 530 5
93 12 25	898 632 125	31.064 449 1	9.881 945 1
93 31 56	901 428 696	31.080 540 5	9.885 357 4
93 50 89	904 231 063	31.096 623 6	9.888 767 3
93 70 24	907 039 232	31.112 698 4	9.892 174 9
93 89 61	909 853 209	31.128 764 8	9.895 580 1
94 09 00	912 673 000	31.144 823	9.898 983
94 28 41	915 498 611	31.160 872 9	9.902 383 5
94 47 84	918 330 048	31.176 914 5	9.905 781 7
94 67 29	921 167 317	31.192 947 9	9.909 177 6
94 86 76	924 010 424	31.208 973 1	9.912 571 2
95 06 25	926 859 375	31.224 99	9.915 962 4
95 25 76	929 714 176	31.240 998 7	9.919 351 3
95 45 29	932 574 833	31.256 999 2	9.922 737 9
95 64 84	935 441 352	31.272 991 5	9.926 122 2
95 84 41	938 313 739	31.288 975 7	9.929 504 2
96 04 00	941 192 000	31.304 951 7	9.932 883 9
96 23 61	944 076 141	31.320 919 5	9.936 261 3
96 43 24	946 966 168	31.336 879 2	9.939 636 3
96 62 89	949 862 087	31.352 830 8	9.943 009 2
96 82 56	952 763 904	31.368 774 3	9.946 379 7
97 02 25	955 671 625	31.384 709 7	9.949 747 9
97 21 96	958 585 256	31.400 636 9	9.953 113 8
97 41 69	961 504 803	31.416 556 1	9.956 477 5
97 61 44	964 430 272	31.432 467 3	9.959 838 9
97 81 21	967 361 669	31.448 370 4	9.963 198 1
98 01 00	970 299 000	31.464 265 4	9.966 554 9
98 20 81	973 242 271	31.480 152 5	9.969 909 5
98 40 64	976 191 488	31.496 031 5	9.973 261 9
98 60 49	979 146 657	31.511 902 5	9.976 612
98 80 36	982 107 784	31.527 765 5	9.979 959 9
99 00 25	985 074 875	31.543 620 6	9.983 305 5
99 20 16	988 047 936	31.559 467 7	9.986 648 8
99 40 09	991 026 973	31.575 306 8	9.989 99
99 60 04	994 011 992	31.591 138	9.993 328 9
99 80 01	997 002 999	31.606 961 3	9.996 665 6
1 00 00 00	1 000 000 000	31.622 776 6	10
1 00 20 01	1 003 003 001	31.638 584	10
1 00 40 04	1 006 012 008	31.654 383 6	[illegible]
1 00 60 09	1 009 027 027	31.670 175 2	[illegible]
1 00 80 16	1 012 048 064	31.685 959	
1 01 00 25	1 015 075 125	31.701 734 9	
1 01 20 36	1 018 108 216	31.717 503	

Number.	Square.	Cube.	Square Root.	Cube Root.
1007	1 01 40 49	1 021 147 343	31.733 263 3	10.023 279 1
1008	1 01 60 64	1 024 192 512	31.749 015 7	10.026 595 8
1009	1 01 80 81	1 027 243 729	31.764 760 3	10.029 910 4
1010	1 02 01 00	1 030 301 000	31.780 497 2	10.033 222 8
1011	1 02 21 21	1 033 364 331	31.796 226 2	10.036 533
1012	1 02 41 44	1 036 433 728	31.811 947 4	10.039 841
1013	1 02 61 69	1 039 509 197	31.827 660 9	10.043 146 9
1014	1 02 81 96	1 042 590 744	31.843 366 6	10.046 450 6
1015	1 03 02 25	1 045 678 375	31.859 064 6	10.049 752 1
1016	1 03 22 56	1 048 772 096	31.874 754 9	10.053 051 4
1017	1 03 42 89	1 051 871 913	31.890 437 4	10.056 348 5
1018	1 03 63 24	1 054 977 832	31.906 112 3	10.059 643 5
1019	1 03 83 61	1 058 089 859	31.921 779 4	10.062 936 4
1020	1 04 04 00	1 061 208 000	31.937 438 8	10.066 227 1
1021	1 04 24 41	1 064 332 261	31.953 090 6	10.069 515 6
1022	1 04 44 84	1 067 462 648	31.968 734 7	10.072 802
1023	1 04 65 29	1 070 599 167	31.984 371 2	10.076 086 3
1024	1 04 85 76	1 073 741 824	32	10.079 368 4
1025	1 05 06 25	1 076 890 625	32.015 621 2	10.082 648 4
1026	1 05 26 76	1 080 045 576	32.031 234 8	10.085 926 2
1027	1 05 47 29	1 083 206 683	32.046 840 7	10.089 201 9
1028	1 05 67 84	1 086 373 952	32.062 439 1	10.092 475 5
1029	1 05 88 41	1 089 547 389	32.078 029 8	10.095 746 9
1030	1 06 09 00	1 092 727 000	32.093 613 1	10.099 016 3
1031	1 06 29 61	1 095 912 791	32.109 188 7	10.102 283 5
1032	1 06 50 24	1 099 104 768	32.124 756 8	10.105 548 7
1033	1 06 70 89	1 102 302 937	32.140 317 3	10.108 811 7
1034	1 06 91 56	1 105 507 304	32.155 870 4	10.112 072 6
1035	1 07 12 25	1 108 717 875	32.171 415 9	10.115 331 4
1036	1 07 32 96	1 111 934 656	32.186 953 9	10.118 588 2
1037	1 07 53 69	1 115 157 653	32.202 484 4	10.121 842 8
1038	1 07 74 44	1 118 386 872	32.218 007 4	10.125 095 3
1039	1 07 95 21	1 121 622 319	32.233 522 9	10.128 345 7
1040	1 08 16 00	1 124 864 000	32.249 031	10.131 594 1
1041	36 81	1 128 111 921	32.264 531 6	10.134 840 3
10[illegible]	08 57 64	1 131 366 088	32.280 024 8	10.138 084 5
[illegible]43	1 08 78 49	1 134 626 507	32.295 510 5	10.141 326 6
1044	1 08 99 36	1 137 893 184	32.310 988 8	10.144 566 7
45	1 09 20 25	1 141 166 125	32.326 459 8	10.147 804 7
46	1 09 41 16	1 144 445 336	32.341 923 3	10.151 040 6
7	1 09 62 09	1 147 730 823	32.357 379 4	10.154 274 4
8	1 09 83 04	1 151 022 592	32.372 828 1	10.157 506 2
	1 10 04 01	1 154 320 649	32.388 269 5	10.160 735 9
	1 10 25 00	1 157 625 000	32.403 703 5	10.163 963 6
	1 10 46 01	1 160 935 651	32.419 130 1	10.167 189 3
	1 10 67 04	1 164 252 608	32.434 549 5	10.170 412 9
	1 10 88 09	1 167 575 877	32.449 961 5	10.173 634 4
	1 11 09 16	1 170 905 464	32.465 366 2	10.176 853 9
	1 11 30 25	1 174 241 375	32.480 763 5	10.180 071 4
	1 11 51 36	1 177 583 616	32.496 153 6	10.183 286 8
	1 11 72 49	1 180 932 193	32.511 536 4	10.186 500 2
	11 93 64	1 184 287 112	32.526 911 9	10.189 711 6
	12 14 81	1 187 648 379	32.542 280 2	10.192 920 9
	12 36 00	1 191 016 000	32.557 641 2	10.196 128 3
	12 57 21	1 194 389 981	32.572 994 9	10.199 333 6
	1 12 78 44	1 197 770 328	32.588 341 5	10.202 536 9

Square.	Cube.	Square Root.	Cube Root.
1 12 99 69	1 201 157 047	32.603 680 7	10.205 738 2
1 13 20 96	1 204 550 144	32.619 012 9	10.208 937 5
1 13 42 25	1 207 949 625	32.634 337 7	10.212 134 7
1 13 63 56	1 211 355 496	32.649 655 4	10.215 33
1 13 84 89	1 214 767 763	32.664 965 9	10.218 523 3
1 14 06 24	1 218 186 432	32.680 269 3	10.221 714 6
1 14 27 61	1 221 611 509	32.695 565 4	10.224 903 9
1 14 49 00	1 225 043 000	32.710 854 4	10.228 091 2
1 14 70 41	1 228 480 911	32.726 136 3	10.231 276 6
1 14 91 84	1 231 925 248	32.741 411 1	10.234 459 9
1 15 13 29	1 235 376 017	32.756 678 7	10.237 641 3
1 15 34 76	1 238 833 224	32.771 939 2	10.240 820 7
1 15 56 25	1 242 296 875	32.787 192 6	10.243 998 1
1 15 77 76	1 245 766 976	32.802 438 9	10.247 173 5
1 15 99 29	1 249 243 533	32.817 678 2	10.250 347
1 16 20 84	1 252 726 552	32.832 910 3	10.253 518 6
1 16 42 41	1 256 216 039	32.848 135 4	10.256 688 1
1 16 64 00	1 259 712 000	32.863 353 5	10.259 855 7
1 16 85 61	1 263 214 441	32.878 564 4	10.263 021 3
1 17 07 24	1 266 723 368	32.893 768 4	10.266 185
1 17 28 89	1 270 238 787	32.908 965 3	10.269 346 7
1 17 50 56	1 273 760 704	32.924 155 3	10.272 506 5
1 17 72 25	1 277 289 125	32.939 338 2	10.275 664 4
1 17 93 96	1 280 824 056	32.954 514 1	10.278 820 3
1 18 15 69	1 284 365 503	32.969 683	10.281 974 3
1 18 37 44	1 287 913 472	32.984 845	10.285 126 4
1 18 59 21	1 291 467 969	33	10.288 276 5
1 18 81 00	1 295 029 000	33.015 148	10.291 424 7
1 19 02 81	1 298 596 571	33.030 289 1	10.294 570 9
1 19 24 64	1 302 170 688	33.045 423 3	10.297 715 3
1 19 46 49	1 305 751 357	33.060 550 5	10.300 857 7
1 19 68 36	1 309 338 584	33.075 670 8	10.303 998 2
1 19 90 25	1 312 932 375	33.090 784 2	10.307 136 8
1 20 12 16	1 316 532 736	33.105 890 7	10.310 273 5
1 20 34 09	1 320 139 673	33.120 990 3	10.313 408 3
1 20 56 04	1 323 753 192	33.136 083	10.316 54
1 20 78 01	1 327 373 299	33.151 168 9	10.319 67 57
1 21 00 00	1 331 000 000	33.166 247 9	10.322 8890 2
1 21 22 01	1 334 633 301	33.181 32	10.325 921 7
1 21 44 04	1 338 273 208	33.196 385 3	10.329 0537
1 21 66 09	1 341 919 727	33.211 443 8	10.332 177
1 21 88 16	1 345 572 864	33.226 695 5	10.335 298 5
1 22 10 25	1 349 232 625	33.241 540 3	10.338 418 1
1 22 32 36	1 352 899 016	33.256 578 3	10.341 53
1 22 54 49	1 356 572 043	33.271 609 5	10.344 6
1 22 76 64	1 360 251 712	33.286 633 9	10.347
1 22 98 81	1 363 938 029	33.301 651 6	10.350
1 23 21 00	1 367 631 000	33.316 662 5	10.353
1 23 43 21	1 371 330 631	33.331 666 6	10.357
1 23 65 44	1 375 036 928	33.346 664	10.360
1 23 87 69	1 378 749 897	33.361 654 6	10.363
1 24 09 96	1 382 469 544	33.376 638 5	10.366
1 24 32 25	1 386 195 875	33.391 615 7	10.369 5
1 24 54 56	1 389 928 896	33.406 586 2	10.372 6
1 24 76 89	1 393 668 613	33.421 549 9	10.375 7
1 24 99 24	1 397 415 032	33.436 507	10.378 803

Number.	Square.	Cube.	Square Root.	Cube Root.
1119	1 25 21 61	1 401 168 159	33.451 457 3	10.381 896 5
1120	1 25 44 00	1 404 928 000	33.466 401 1	10.384 988 2
1121	1 25 66 41	1 408 694 561	33.481 338 1	10.388 078 1
1122	1 25 88 84	1 412 467 848	33.496 268 4	10.391 166 1
1123	1 26 11 29	1 416 247 867	33.511 192 1	10.394 252 3
1124	1 26 33 76	1 420 034 624	33.526 109 2	10.397 336 6
1125	1 26 56 25	1 423 828 125	33.541 019 6	10.400 419 2
1126	1 26 78 76	1 427 628 376	33.555 923 4	10.403 499 9
1127	1 27 01 29	1 431 435 383	33.570 820 6	10.406 578 7
1128	1 27 23 84	1 435 249 152	33.585 711 2	10.409 655 7
1129	1 27 46 41	1 439 069 689	33.600 595 2	10.412 731
1130	1 27 69 00	1 442 897 000	33.615 472 6	10.415 804 4
1131	1 27 91 61	1 446 731 091	33.630 343 4	10.418 876
1132	1 28 14 24	1 450 571 968	33.645 207 7	10.421 945 8
1133	1 28 36 89	1 454 419 637	33.660 065 3	10.425 013 8
1134	1 28 59 56	1 458 274 104	33.674 916 5	10.428 08
1135	1 28 82 25	1 462 135 375	33.689 761	10.431 144 3
1136	1 29 04 96	1 466 003 456	33.704 599 1	10.434 206 9
1137	1 29 27 69	1 469 878 353	33.719 430 6	10.437 267 7
1138	1 29 50 44	1 473 760 072	33.734 255 6	10.440 326 7
1139	1 29 73 21	1 477 648 619	33.749 074 1	10.443 383 9
1140	1 29 96 00	1 481 544 000	33.763 886 0	10.446 439 3
1141	1 30 18 81	1 485 446 221	33.778 691 5	10.449 492 9
1142	1 30 41 64	1 489 355 288	33.793 490 5	10.452 544 8
1143	1 30 64 49	1 493 271 207	33.808 283	10.455 594 8
1144	1 30 87 36	1 497 193 984	33.823 069 1	10.458 643 1
1145	1 31 10 25	1 501 123 625	33.837 848 6	10.461 689 6
1146	1 31 33 16	1 505 060 136	33.852 621 8	10.464 734 3
1147	1 31 56 09	1 509 603 523	33.867 388 4	10.467 777 3
1148	1 31 79 04	1 512 953 792	33.882 148 7	10.470 818 5
1149	1 32 02 01	1 516 910 949	33.896 902 5	10.473 857 9
1150	1 32 25 00	1 520 875 000	33.911 649 9	10.476 895 5
1151	1 32 48 01	1 524 845 951	33.926 390 9	10.479 931 4
1152	1 32 71 04	1 528 823 808	33.941 125 5	10.482 965 6
[illegible]	1 32 94 09	1 532 808 577	33.955 853 7	10.485 998
[illegible]	1 33 17 16	1 536 800 264	33.970 575 5	10.489 028 6
[illegible]	1 33 40 25	1 540 798 875	33.985 291	10.492 057 5
[illegible]	1 33 63 36	1 544 804 416	34	10.495 084 7
[illegible]	1 33 86 49	1 548 816 893	34.014 702 7	10.498 110 1
[illegible]	1 34 09 64	1 552 836 312	34.029 399	10.501 133 7
	1 34 32 81	1 556 862 679	34.044 089	10.504 155 6
	1 34 56 00	1 560 896 000	34.058 772 7	10.507 175 7
	1 34 79 21	1 564 936 281	34.073 450 1	10.510 194 2
	1 35 02 44	1 568 983 528	34.088 121 1	10.513 210 9
	35 25 69	1 573 037 747	34.102 785 8	10.516 225 9
	35 48 96	1 577 098 944	34.117 444 2	10.519 239 1
	35 72 25	1 581 167 125	34.132 096 3	10.522 250 6
	35 95 56	1 585 242 296	34.146 742 2	10.525 260 4
	1 36 18 89	1 589 324 463	34.161 381 7	10.528 268 5
	1 36 42 24	1 593 413 632	34.176 015	10.531 274 9
	36 65 61	1 597 509 809	34.190 642	10.534 279 5
	36 89 00	1 601 613 000	34.205 262 7	10.537 282 5
	7 12 41	1 605 723 211	34.219 877 3	10.540 283 7
	35 84	1 609 840 448	34.234 485 5	10.543 283 2
	59 29	1 613 964 717	34.249 087 5	10.546 281
	82 76	1 618 096 024	34.263 683 4	10.549 277

Square.	Cube.	Square Root.	Cube Root.
1 38 06 25	1 622 234 375	34.278 273	10.552 271 5
1 38 29 76	1 626 379 776	34.292 856 4	10.555 264 2
1 38 53 29	1 630 532 233	34.307 433 6	10.558 255 2
1 38 76 84	1 634 691 752	34.322 004 6	10.561 244 5
1 39 00 41	1 638 858 339	34.336 569 4	10.564 232 2
1 39 24 00	1 643 032 000	34.351 128 1	10.567 218 1
1 39 47 61	1 647 212 741	34.365 680 5	10.570 202 4
1 39 71 24	1 651 400 568	34.380 226 8	10.573 184 9
1 39 94 89	1 655 595 487	34.394 767	10.576 165 8
1 40 18 56	1 659 797 504	34.409 301 1	10.579 144 9
1 40 42 25	1 664 006 625	34.423 828 9	10.582 122 5
1 40 65 96	1 668 222 856	34.438 350 7	10.585 098 3
1 40 89 69	1 672 446 203	34.452 866 3	10.588 072 5
1 41 13 44	1 676 676 672	34.467 375 9	10.591 045
1 41 37 21	1 680 914 269	34.481 879 3	10.594 015 8
1 41 61 00	1 685 159 000	34.496 376 6	10.596 985
1 41 84 81	1 689 410 871	34.510 867 8	10.599 952 5
1 42 08 64	1 693 669 888	34.525 353	10.602 918 4
1 42 32 49	1 697 936 057	34.539 832 1	10.605 882 6
1 42 56 36	1 702 209 384	34.554 305 1	10.608 845 1
1 42 80 25	1 706 489 875	34.568 772	10.611 806
1 43 04 16	1 710 777 536	34.583 232 9	10.614 765 2
1 43 28 09	1 715 072 373	34.597 687 9	10.617 722 8
1 43 52 04	1 719 374 392	34.612 136 6	10.620 678 8
1 43 76 01	1 723 683 599	34.626 579 4	10.623 633 1
1 44 00 00	1 728 000 000	34.641 016 2	10.626 585 7
1 44 24 01	1 732 323 601	34.655 446 9	10.629 536 7
1 44 48 04	1 736 654 408	34.669 871 6	10.632 486
1 44 72 09	1 740 992 427	34.684 290 4	10.635 433 8
1 44 96 16	1 745 337 664	34.698 703 1	10.638 379 9
1 45 20 25	1 749 690 125	34.713 109 9	10.641 324 4
1 45 44 36	1 754 049 816	34.727 510 7	10.644 267 2
1 45 68 49	1 758 416 743	34.741 905 5	10.647 208 5
1 45 92 64	1 762 790 912	34.756 294 4	10.650 148
1 46 16 81	1 767 172 329	34.770 677 3	10.653 086
1 46 41 00	1 771 561 000	34.785 054 3	10.656 022 3
1 46 65 21	1 775 956 931	34.799 425 3	10.658 957
1 46 89 44	1 780 360 128	34.813 790 4	10.661 890 2
1 47 13 69	1 784 770 597	34.828 149 5	10.664 821 7
1 47 37 96	1 789 188 344	34.842 502 8	10.667 751 6
1 47 62 25	1 793 613 375	34.856 850 1	10.670 679 9
1 47 86 56	1 798 045 696	34.871 191 5	10.673 606 6
1 48 10 89	1 802 485 313	34.885 527 1	10.676 [illegible]
1 48 35 24	1 806 932 232	34.899 856 7	10.6[illegible]
1 48 59 61	1 811 386 459	34.914 180 5	[illegible]
1 48 84 00	1 815 848 000	34.928 498 4	[illegible]
1 49 08 41	1 820 316 861	34.942 810 4	[illegible]
1 49 32 84	1 824 793 048	34.957 116 6	[illegible]
1 49 57 29	1 829 276 567	34.971 416 9	[illegible]
1 49 81 76	1 833 767 424	34.985 711 4	[illegible]
1 50 06 25	1 838 265 625	35	[illegible]
1 50 30 76	1 842 771 176	35.014 282 8	[illegible]
1 50 55 29	1 847 284 083	35.028 559 8	[illegible]
1 50 79 84	1 851 804 352	35.042 830 9	10.70[illegible]
1 51 04 41	1 856 331 989	35.057 096 3	10.711 [illegible]
1 51 29 00	1 860 867 000	35.071 355 8	10.714 [illegible]

Number.	Square.	Cube.	Square Root.	Cube Root.
1231	1 51 53 61	1 865 409 391	35.085 609 6	10.717 315 5
1232	1 51 78 24	1 869 959 168	35.099 857 5	10.720 216 8
1233	1 52 02 89	1 874 516 337	35.114 099 7	10.723 116 5
1234	1 52 27 56	1 879 080 904	35.128 336 1	10.726 014 6
1235	1 52 52 25	1 883 652 875	35.142 556 8	10.728 911 2
1236	1 52 76 96	1 888 232 256	35.156 791 7	10.731 806 2
1237	1 53 01 69	1 892 819 053	35.171 010 8	10.734 699 7
1238	1 53 26 44	1 897 413 272	35.185 224 2	10.737 591 6
1239	1 53 51 21	1 902 014 919	35.199 431 8	10.740 481 9
1240	1 53 76 00	1 906 624 000	35.213 633 7	10.743 370 7
1241	1 54 00 81	1 911 240 521	35.227 829 9	10.746 257 9
1242	1 54 25 64	1 915 864 488	35.242 020 4	10.749 143 6
1243	1 54 50 49	1 920 495 907	35.256 205 1	10.752 027 7
1244	1 54 75 36	1 925 134 784	35.270 384 2	10.754 910 3
1245	1 55 00 25	1 929 781 125	35.284 557 5	10.757 791 3
1246	1 55 25 16	1 934 434 936	35.298 725 2	10.760 670 8
1247	1 55 50 09	1 939 096 223	35.312 887 2	10.763 548 8
1248	1 55 75 04	1 943 764 992	35.327 043 5	10.766 425 2
1249	1 56 00 01	1 948 441 249	35.341 194 1	10.769 300 1
1250	1 56 25 00	1 953 125 000	35.355 339 1	10.772 173 5
1251	1 56 50 01	1 957 816 251	35.369 478 4	10.775 045 3
1252	1 56 75 04	1 962 515 008	35.383 612	10.777 915 6
1253	1 57 00 09	1 967 221 277	35.397 74	10.780 784 3
1254	1 57 25 16	1 971 935 064	35.411 862 4	10.783 651 6
1255	1 57 50 25	1 976 656 375	35.425 979 2	10.786 517 3
1256	1 57 75 36	1 981 385 216	35.440 090 3	10.789 381 5
1257	1 58 00 49	1 986 121 593	35.454 195 8	10.792 244 1
1258	1 58 25 64	1 990 865 512	35.468 295 7	10.795 105 3
1259	1 58 50 81	1 995 616 979	35.482 39	10.797 964 9
1260	1 58 76 00	2 000 376 000	35.496 478 7	10.800 823
1261	1 59 01 21	2 005 142 581	35.510 561 8	10.803 679 7
1262	1 59 26 44	2 009 916 728	35.524 639 3	10.806 534 8
1263	1 59 51 69	2 014 698 447	35.538 711 3	10.809 388 4
1264	1 59 76 96	2 019 487 744	35.552 777 7	10.812 240 4
1265	1 60 02 25	2 024 284 625	35.566 838 5	10.815 090 9
1266	1 60 27 56	2 029 089 096	35.580 893 7	10.817 94
1267	1 60 52 89	2 033 901 163	35.594 943 4	10.820 787 6
1268	1 60 78 24	2 038 720 832	35.608 987 6	10.823 633 6
1269	1 61 03 61	2 043 548 109	35.623 026 2	10.826 478 2
1270	1 61 29 00	2 048 383 000	35.637 059 3	10.829 321 3
1271	1 61 54 41	2 053 225 511	35.651 086 9	10.832 162 9
1272	1 61 79 84	2 058 075 648	35.665 109	10.835 003
1273	1 62 05 29	2 062 933 417	35.679 125 5	10.837 841 6
1274	1 62 30 76	2 067 798 824	35.693 136 6	10.840 678 8
1275	1 62 56 25	2 072 671 875	35.707 142 1	10.843 514 4
1276	1 62 81 76	2 077 552 576	35.721 142 2	10.846 348 5
1277	1 63 07 29	2 082 440 933	35.735 136 7	10.849 181 2
1278	1 63 32 84	2 087 336 952	35.749 125 8	10.852 012 5
[illegible]	1 63 58 41	2 092 240 639	35.763 109 5	10.854 842 2
	1 63 84 00	2 097 152 000	35.777 087 6	10.857 670 4
	1 64 09 61	2 102 071 041	35.791 060 3	10.860 497 2
	[illegible] 24	2 106 997 768	35.805 027 6	10.863 322 5
	[illegible]9	2 111 932 187	35.818 989 4	10.866 146 4
	[illegible]6	2 116 874 304	35.832 945 7	10.868 968 7
	[illegible]	2 121 824 125	35.846 896 6	10.871 789 7
		2 126 781 656	35.860 842 1	10.874 609

n.	Square.	Cube.	Square Root.	Cube Root.
	1 65 63 69	2 131 746 903	35.874 782 2	10.877 427 1
	1 65 89 44	2 136 719 872	35.888 716 9	10.880 243 6
	1 66 15 21	2 141 700 569	35.902 646 1	10.883 058 7
	1 66 41 00	2 146 689 000	35.916 569 9	10.885 872 3
	1 66 66 81	2 151 685 171	35.930 488 4	10.888 684 5
	1 66 92 64	2 156 689 088	35.944 401 5	10.891 495 2
	1 67 18 49	2 161 700 757	35.958 309 2	10.894 304 4
	1 67 44 36	2 166 720 184	35.972 211 5	10.897 112 3
	1 67 70 25	2 171 747 375	35.986 108 4	10.899 918 6
	1 67 96 16	2 176 782 336	36	10.902 723 5
	1 68 22 09	2 181 825 073	36.013 886 2	10.905 526 9
	1 68 48 04	2 186 875 592	36.027 767 1	10.908 329
	1 68 74 01	2 191 933 899	36.041 642 6	10.911 129 6
	1 69 00 00	2 197 000 000	36.055 512 8	10.913 928 7
	1 69 26 01	2 202 073 901	36.069 377 6	10.916 726 5
	1 69 52 04	2 207 155 608	36.083 237 1	10.919 522 8
	1 69 78 09	2 212 245 127	36.097 091 3	10.922 317 7
	1 70 04 16	2 217 342 464	36.110 940 2	10.925 111 1
	1 70 30 25	2 222 447 625	36.124 783 7	10.927 903 1
	1 70 56 36	2 227 560 616	36.138 622	10.930 693 7
	1 70 82 49	2 232 681 443	36.152 455	10.933 482 9
	1 71 08 64	2 237 810 112	36.166 282 6	10.936 270 6
	1 71 34 81	2 242 946 629	36.180 105	10.939 056 9
	1 71 61 00	2 248 091 000	36.193 922 1	10.941 841 8
	1 71 87 21	2 253 243 231	36.207 734	10.944 625 3
	1 72 13 44	2 258 403 328	36.221 540 6	10.947 507 4
	1 72 39 69	2 263 571 297	36.235 341 9	10.950 188
	1 72 65 96	2 268 747 144	36.249 137 9	10.952 967 3
	1 72 92 25	2 273 930 875	36.262 928 7	10.955 745 1
	1 73 18 56	2 279 122 496	36.276 714 3	10.958 521 5
	1 73 44 89	2 284 322 013	36.290 494 6	10.961 296 5
	1 73 71 24	2 289 529 432	36.304 269 7	10.964 070 1
	1 73 97 61	2 294 744 759	36.318 039 6	10.966 842 3
	1 74 24 00	2 299 968 000	36.331 804 2	10.969 613 1
	1 74 50 41	2 305 199 161	36.345 563 7	10.972 382 5
	1 74 76 84	2 310 438 248	36.359 317 9	10.975 150 5
	1 75 03 29	2 315 685 267	36.373 067	10.977 917 1
	1 75 29 76	2 320 940 224	36.386 810 8	10.980 682 3
	1 75 56 25	2 326 203 125	36.400 549 4	10.983 446 2
	1 75 82 76	2 331 473 976	36.414 282 9	10.986 208 6
	1 76 09 29	2 336 752 783	36.428 011 2	10.988 969 6
	1 76 35 84	2 342 039 552	36.441 734 3	10.991 729 3
	1 76 62 41	2 347 334 289	36.455 452 3	10.994 487 6
	1 76 89 00	2 352 637 000	36.469 165	10
	1 77 15 61	2 357 947 691	36.482 872 7	
	1 77 42 24	2 363 266 368	36.496 575 2	
	1 77 68 89	2 368 593 037	36.510 272 5	
	1 77 95 56	2 373 927 704	36.523 964 7	
	1 78 22 25	2 379 270 375	36.537 651 8	
	1 78 48 96	2 384 621 056	36.551 333 8	
	1 78 75 69	2 389 979 753	36.565 010 6	
	1 79 02 44	2 395 346 472	36.578 682 3	1.
	1 79 29 21	2 400 721 219	36.592 348 9	11.
	1 79 56 00	2 406 104 000	36.606 010 4	11.0
	1 79 82 81	2 411 494 821	36.619 666 8	11.027
	1 80 09 64	2 416 893 688	36.633 318 1	11.030 2

Number.	Square.	Cube.	Square Root.	Cube Root.
1343	1 80 36 49	2 422 300 607	36.646 964 4	11.032 959
1344	1 80 63 36	2 427 715 584	36.660 605 6	11.035 696 7
1345	1 80 90 25	2 433 138 625	36.674 241 6	11.038 433
1346	1 81 17 16	2 438 569 736	36.687 872 6	11.041 168
1347	1 81 44 09	2 444 008 923	36.701 498 6	11.043 901 7
1348	1 81 71 04	2 449 456 192	36.715 119 5	11.046 633 9
1349	1 81 98 01	2 454 911 549	36.728 735 3	11.049 364 9
1350	1 82 25 00	2 460 375 000	36.742 346 1	11.052 094 5
1351	1 82 52 01	2 465 846 551	36.755 951 9	11.054 822 7
1352	1 82 79 04	2 471 326 208	36.769 552 6	11.057 549 7
1353	1 83 06 09	2 476 813 977	36.783 148 3	11.060 275 2
1354	1 83 33 16	2 482 309 864	36.796 739	11.062 999 4
1355	1 83 60 25	2 487 813 875	36.810 324 6	11.065 722 2
1356	1 83 87 36	2 493 326 016	36.823 905 3	11.068 443 7
1357	1 84 14 49	2 498 846 293	36.837 480 9	11.071 163 9
1358	1 84 41 64	2 504 374 712	36.851 051 5	11.073 882 8
1359	1 84 68 81	2 509 911 279	36.864 617 2	11.076 600 3
1360	1 84 96 00	2 515 456 000	36.878 177 8	11.079 316 5
1361	1 85 23 21	2 521 008 881	36.891 733 5	11.082 031 4
1362	1 85 50 44	2 526 569 928	36.905 284 2	11.084 744 9
1363	1 85 77 69	2 532 139 147	36.918 829 9	11.087 457 1
1364	1 86 04 96	2 537 716 544	36.932 370 6	11.090 167 9
1365	1 86 32 25	2 543 302 125	36.945 906 4	11.092 877 5
1366	1 86 59 56	2 548 895 896	36.959 437 2	11.095 585 7
1367	1 86 86 89	2 554 497 863	36.972 963 1	11.098 292 6
1368	1 87 14 24	2 560 108 032	36.986 484	11.100 998 2
1369	1 87 41 61	2 565 726 409	37	11.103 702 5
1370	1 87 69 00	2 571 353 000	37.013 511	11.106 405 4
1371	1 87 96 41	2 576 987 811	37.027 017 2	11.109 107
1372	1 88 23 84	2 582 630 848	37.040 518 4	11.111 807 3
1373	1 88 51 29	2 588 282 117	37.054 014 6	11.114 506 4
1374	1 88 78 76	2 593 941 624	37.067 506	11.117 204 1
1375	1 89 06 25	2 599 609 375	37.089 992 4	11.119 900 4
1376	1 89 33 76	2 605 285 376	37.094 474	11.122 595 5
1377	1 89 61 29	2 610 969 633	37.107 950 6	11.125 289 3
1378	1 89 88 84	2 616 662 152	37.121 422 4	11.127 981 7
1379	1 90 16 41	2 622 362 939	37.134 889 3	11.130 672 9
1380	1 90 44 00	2 628 072 000	37.148 351 2	11.133 362 8
1381	1 90 71 61	2 633 789 341	37.161 808 4	11.136 051 4
1382	1 90 99 24	2 639 514 968	37.175 260 6	11.138 738 6
1383	1 91 26 89	2 645 248 887	37.188 707 9	11.141 424 6
1384	1 91 54 56	2 650 991 104	37.202 150 5	11.144 109 3
1385	1 91 82 25	2 656 741 625	37.215 588 1	11.146 792 6
1386	1 92 09 96	2 662 500 456	37.229 020 9	11.149 474 7
1387	1 92 37 69	2 668 267 603	37.242 448 9	11.152 155 5
1388	1 92 65 44	2 674 043 072	37.255 872	11.154 835
[illegible]	1 92 93 21	2 679 826 869	37.269 290 3	11.157 513 3
[illegible]	1 93 21 00	2 685 619 000	37.282 703 7	11.160 190 3
[illegible]	1 93 48 81	2 691 419 471	37.296 112 4	11.162 865 9
[illegible]	1 93 76 64	2 697 228 288	37.309 516 2	11.165 540 3
[illegible]	1 94 04 49	2 703 045 457	37.322 915 2	11.168 213 4
[illegible]	94 32 36	2 708 870 984	37.336 309 4	11.170 885 2
[illegible]	94 60 25	2 714 704 875	37.349 698 8	11.173 555 8
[illegible]	[illegible]	2 720 547 136	37.363 083 4	11.176 225
[illegible]	[illegible]	26 397 773	37.376 463 2	11.178 893
[illegible]	[illegible]	2 256 792	37.389 838 2	11.181 559

[illegible]ER.	SQUARE.	CUBE.	SQUARE ROOT.	CUBE ROOT.
9	1 95 72 01	2 738 124 199	37.403 208 4	11.184 225 2
0	1 96 00 00	2 744 000 000	37.416 573 8	11.186 889 4
1	1 96 28 01	2 749 884 201	37.429 934 5	11.189 552 3
2	1 96 56 04	2 755 776 808	37.443 290 4	11.192 213 9
3	1 96 84 09	2 761 677 827	37.456 641 6	11.194 874 3
4	1 97 12 16	2 767 587 264	37.469 988	11.197 533 4
5	1 97 40 25	2 773 505 125	37.483 329 6	11.200 191 3
6	1 97 68 36	2 779 431 416	37.496 666 5	11.202 847 9
7	1 97 96 49	2 785 366 143	37.509 998 7	11.205 503 2
8	1 98 24 64	2 791 309 312	37.523 326 1	11.208 157 3
9	1 98 52 81	2 797 260 929	37.536 648 7	11.210 810 1
0	1 98 81 00	2 803 221 000	37.549 966 7	11.213 461 7
1	1 99 09 21	2 809 189 531	37.563 279 9	11.216 112
2	1 99 37 44	2 815 166 528	37.576 588 5	11.218 761 1
3	1 99 65 69	2 821 151 997	37.589 892 2	11.221 408 9
4	1 99 93 96	2 827 145 944	37.603 191 3	11.224 005 4
5	2 00 22 25	2 833 148 375	37.616 485 7	11.226 700 7
6	2 00 50 56	2 839 159 296	37.629 775 4	11.229 344 8
7	2 00 78 89	2 845 178 713	37.643 060 4	11.231 987 6
8	2 01 07 24	2 851 206 632	37.656 340 7	11.234 629 2
9	2 01 35 61	2 857 243 059	37.669 616 4	11.237 269 6
0	2 01 64 00	2 863 288 000	37.682 887 4	11.239 908 7
1	2 01 92 41	2 869 341 461	37.696 153 6	11.242 546 5
2	2 02 20 84	2 875 403 448	37.709 415 3	11.245 183 1
3	2 02 49 29	2 881 473 967	37.722 672 2	11.247 818 5
4	2 02 77 76	2 887 553 024	37.735 924 5	11.250 452 7
5	2 03 06 25	2 893 640 625	37.749 172 2	11.253 085 6
6	2 03 34 76	2 899 736 776	37.762 415 2	11.255 717 3
7	2 03 63 29	2 905 841 483	37.775 653 5	11.258 347 8
8	2 03 91 84	2 911 954 752	37.788 887 3	11.260 977
9	2 04 20 41	2 918 076 589	37.802 116 3	11.263 605
0	2 04 49 00	2 924 207 000	37.815 340 8	11.266 231 8
1	2 04 77 61	2 930 345 991	37.828 560 6	11.268 857 3
2	2 05 06 24	2 936 493 568	37.841 775 9	11.271 481 6
3	2 05 34 89	2 942 649 737	37.854 986 4	11.274 104 7
4	2 05 63 56	2 948 814 504	37.868 192 4	11.276 726 6
5	2 05 92 25	2 954 987 875	37.881 393 8	11.279 347 2
6	2 06 20 96	2 961 169 856	37.894 590 6	11.281 966 6
7	2 06 49 69	2 967 360 453	37.907 782 8	11.284 584 9
8	2 06 78 44	2 973 559 672	37.920 970 4	11.287 201 9
9	2 07 07 21	2 979 767 519	37.934 153 5	11.289 817 7
0	2 07 36 00	2 985 984 000	37.947 331 9	11.292 432 3
1	2 07 64 81	2 992 209 121	37.960 505 8	11.295 045 7
2	2 07 93 64	2 998 442 888	37.973 675 1	11.297 657 9
3	2 08 22 49	3 004 685 307	37.986 839 8	[illegible]
4	2 08 51 36	3 010 936 384	38	
5	2 08 80 25	3 017 196 125	38.013 155 6	
6	2 09 09 16	3 023 464 536	38.026 306 7	
7	2 09 38 09	3 029 741 623	38.039 453 2	
8	2 09 67 04	3 036 027 392	38.052 595 2	
9	2 09 96 01	3 042 321 849	38.065 732 6	
0	2 10 25 00	3 048 625 000	38.078 865 5	
[illegible]	2 10 54 01	3 054 936 851	38.091 993 9	
	2 10 83 04	3 061 257 408	38.105 117 8	[illegible]
	2 11 12 09	3 067 586 677	38.118 237 1	[illegible]
	2 11 41 16	3 073 924 664	38.131 351 9	11.[illegible]

EXAMPLE.—What is square root of 53.75, and cube root of 843.75?

$\sqrt{54} = 7.3484$	$\sqrt[3]{844} = 9.4503$
$\sqrt{53} = 7.2801$	$\sqrt[3]{843} = 9.4466$
.0683	.0037
.75	.75
.051225	.002775
$\sqrt{53} = 7.2801$	$\sqrt[3]{843} = 9.4466$
$\sqrt{53.75} = 7.331325$	$\sqrt[3]{843.75} = 9.449375$

When the Square or Cube Root is required for Numbers not exceeding Roots given in Table.

Numbers in table are squares and cubes of roots.

RULE.—Find, by table, in column of numbers that number representing figures of integer and decimals for which root is required, and point it off decimally by places of 2 or 3 figures as square or cube root is required; and opposite to it, in column of roots, take root and point off 1 or 2 additional places of decimals to those in root, as square or cube root is required, and result is root required.

EXAMPLE 1.—What are square roots of .15, 1.50, and 15.00?

In table, 15 has for its root 3.87298; hence .387298 = *square root for* .15.
150 has for its root 12.24745; hence 1.224745 = *square root for* 1.50.
1500 has for its root 38.7298; hence 3.87298 = *square root for* 15.

2.—What are cube roots of .15, 1.50, and 15.00?

Add a cipher to each, to give the numbers three places of figures, as .150, 1.500, and 15.000.

In table 150 has for its root 5.3133; hence .53133 = *cube root of* .15.

1500 has for its root 11.447; hence 1.1447 = *cube root of* 1.50.
15 has for its root 2.4662; and 15.000, by addition of 3 places of figures, has 24.662; hence 2.4662 = *cube root of* 15.00.

To Ascertain Square or Cube Roots of Decimals alone.

RULE.—Point off number from decimal point into periods of two or three figures each, as square or cube root is required. Ascertain from table or by calculation root of number corresponding to decimal given, the same being read off by removing the decimal point one place to left for every period of 2 figures if square root is required, and one place for every period of 3 figures if cube root is required.

EXAMPLE.—What are square and cube roots of .810, .081, and .0081?

.810, when pointed off = .81, and $\sqrt{.81}$ = .9.
.081, " " " = .081, " $\sqrt{.081}$ = .2846.
.0081, " " " = .0081, " $\sqrt{.0081}$ = .09.

.810, when pointed off = .810, and $\sqrt[3]{.810}$ = 93217.
.081, " " " = .081, " $\sqrt[3]{.081}$ = .43267.
.0081, " " " = .0081, " $\sqrt[3]{.0081}$ = .20083.

To Compute 4th Root of a Number.

RULE.—Take square root of its square root.

EXAMPLE.—What is the $\sqrt[4]{}$ of 1600?

$\sqrt{1600} = 40$, and $\sqrt{40} = 6.3245553$.

To Compute 6th Root of a Number.

Take cube root of its square root.

—What is the $\sqrt[6]{}$ of 441?

$\sqrt{441} = 21$, and $\sqrt[3]{21} = 2.7589243$.

4th and 5th Powers of Numbers.

From 1 *to* 150.

Number.	4th Power.	5th Power.	Number.	4th Power.	5th Power.
1	1	1	64	16 777 216	1 073 741 824
2	16	32	65	17 850 625	1 160 290 625
3	81	243	66	18 974 736	1 252 332 576
4	256	1 024	67	20 151 121	1 350 125 107
5	625	3 125	68	21 381 376	1 453 933 568
6	1 296	7 776	69	22 667 121	1 564 031 349
7	2 401	16 807	70	24 010 000	1 680 700 000
8	4 096	32 768	71	25 411 681	1 804 229 351
9	6 561	59 049	72	26 873 856	1 934 917 632
10	10 000	100 000	73	28 398 241	2 073 071 593
11	14 641	161 051	74	29 986 576	2 219 006 624
12	20 736	248 832	75	31 640 625	2 373 046 875
13	28 561	371 293	76	33 362 176	2 535 525 376
14	38 416	537 824	77	35 153 041	2 706 784 157
15	50 625	759 375	78	37 015 056	2 887 174 368
16	65 536	1 048 576	79	38 950 081	3 077 056 399
17	83 521	1 419 857	80	40 960 000	3 276 800 000
18	104 976	1 889 568	81	43 046 721	3 486 784 401
19	130 321	2 476 099	82	45 212 176	3 707 398 432
20	160 000	3 200 000	83	47 458 321	3 939 040 643
21	194 481	4 084 101	84	49 787 136	4 182 119 424
22	234 256	5 153 632	85	52 200 625	4 437 053 125
23	279 841	6 436 343	86	54 708 016	4 704 270 176
24	331 776	7 962 624	87	57 289 761	4 984 209 207
25	390 625	9 765 625	88	59 969 536	5 277 319 168
26	456 976	11 881 376	89	62 742 241	5 584 059 449
27	531 441	14 348 907	90	65 610 000	5 904 900 000
28	614 656	17 210 368	91	68 574 961	6 240 321 451
29	707 281	20 511 149	92	71 639 296	6 590 815 232
30	810 000	24 300 000	93	74 805 201	6 956 883 693
31	923 521	28 629 151	94	78 074 896	7 339 040 224
32	1 048 576	33 554 432	95	81 450 625	7 737 809 375
33	1 185 921	39 135 393	96	84 934 656	8 153 726 976
34	1 336 336	45 435 424	97	88 529 281	8 587 340 257
35	1 500 625	52 521 875	98	92 236 816	9 039 207 968
36	1 679 616	60 466 176	99	96 059 601	9 509 900 499
37	1 874 161	69 343 957	100	100 000 000	10 000 000 000
38	2 085 136	79 235 168	101	104 060 401	10 510 100 501
39	2 313 441	90 224 199	102	108 243 216	11 040 808 032
40	2 560 000	102 400 000	103	112 550 881	11 592 740 743
41	2 825 761	115 856 201	104	116 985 856	12 166 529 024
42	3 111 696	130 691 232	105	121 550 625	12 762 815 625
43	3 418 801	147 008 443	106	126 247 696	13 382 255 776
44	3 748 096	164 916 224	107	131 079 601	14 025 517 307
45	4 100 625	184 528 125	108	136 048 896	14 693 280 768
46	4 477 456	205 962 976	109	141 158 161	15 386 239 549
47	4 879 681	229 345 007	110	146 410 000	16 105 100 000
48	5 308 416	254 803 968	111	151 807 041	16 850 581 [illegible]
49	5 764 801	282 475 249	112	157 351 936	17 622 [illegible]
50	6 250 000	312 500 000	113	163 047 361	18 [illegible]
51	6 765 201	345 025 251	114	168 896 016	1[illegible]
52	7 311 616	380 204 032	115	174 900 625	2[illegible]
53	7 890 481	418 195 493	116	181 063 936	2[illegible]
54	8 503 056	459 165 024	117	187 388 721	2[illegible]
55	9 150 625	503 284 375	118	193 877 776	2[illegible]
56	9 834 496	550 731 776	119	200 533 921	2[illegible]
57	10 556 001	601 692 057	120	207 360 000	24[illegible]
58	11 316 496	656 356 768	121	214 358 881	25 [illegible]
59	12 117 361	714 924 299	122	221 533 456	27 0[illegible]
60	12 960 000	777 600 000	123	228 886 641	28 15[illegible]
61	13 845 841	844 596 301	124	236 421 376	29 316 [illegible]
62	14 776 336	916 132 832	125	244 140 625	30 517 5[illegible]
63	15 752 961	992 436 543	126	252 047 376	31 757 969[illegible]

To Subtract a Positive Index. Change its sign to negative, and then add as in addition. As $\bar{2} - 2 = \bar{2} + \bar{2} = \bar{4}$.

To Multiply a Negative Index. Multiply the fractional parts by the ordinary rule, then multiply the negative *index*, which will give a negative product, and when an excess over 10 is to be carried, subtract the less index from the greater, and the remainder gives the positive or negative *index*, according as the positive or negative index is the greater. As $\bar{2} \times 5 = \overline{10}$, and 1 to be carried $= \bar{9}$.

ILLUSTRATION.—Multiply $\bar{2}.3681$ by 2, and $\bar{3}.7856$ by 6.

$$\begin{array}{r} \bar{2}.3681 \\ 2 \\ \hline \bar{4}.7362 \end{array} \qquad \begin{array}{r} \bar{3}.7856 \\ 6 \\ \hline \overline{14}.7136 \end{array}$$

Here $\bar{2} \times 2 = \bar{4}$, also $\bar{3} \times 6 = \overline{18}$, with a positive excess of $4 = \overline{14}$.

To Divide a Negative Index. If *index* is divisible by divisor, without a remainder, put quotient with a negative sign. If negative exponent is not divisible by divisor, add such a negative number to it as will make it divisible, and prefix an equal positive integer to fractional part of logarithm; then divide increased negative exponent and the other part of logarithm separately by ordinary rules, and former quotient, taken negatively, will be *index* to fractional part of quotient. As $\bar{6} \div 3 = \bar{2}$. $\overline{10} \div 3$ requires $\bar{2}$ to be added or 2 to be subtracted, to make it divisible without a remainder, then $\overline{10} + \bar{2} = \overline{12}$, $\overline{12} \div 3 = \bar{4}$, and 2 (the sum subtracted) $\div 3 = .66$, the quotient therefore is $\bar{4}.66$.

ILLUSTRATION 1.—Divide $\bar{6}.324\,282$ by 3.

$$\bar{6}.324\,282 \div 3 = \bar{2}.108\,094.$$

2.—Divide $\overline{14}.326\,745$ by 9.

$$\overline{14}.326\,745 \div 9 = \overline{18} + 4.326\,745 \div 9 = \bar{2}.480\,749+.$$

Here $\bar{4}$ is added to $\overline{14}$, that the sum $\overline{18}$ may be divided by 9, and as $\bar{4}$ is added, 4 must be prefixed to the fractional part of the logarithm, and thus the value of the logarithm is unchanged, for there is added $\bar{4}$, and $4 = 0$, or 4 is subtracted and 4 added.

To Ascertain Logarithm of a Number by Table.

When the Number is less than 101.

Look into first page of table, and opposite to number is its logarithm with its index prefixed.

ILLUSTRATION.—Opposite 7 is .845 098, its logarithm; hence $70 = 1.845\,098$, $.7 = \bar{1}.845\,098$, and $.07 = \bar{2}.845\,098$.

When the Number is between 100 and 1000.

› given number in left-hand column of table headed No., and un-
mn is decimal part of its logarithm, to which is to be prefixed a
an *index*, of 1 or 2, according as the number consists of 2 or 3

t is logarithm of 450, and what of .45?

Log. $450 = 2.653\,213$, and of $.45 = \bar{1}.653\,213$.

When the Number is between 1000 and 10 000.

...hand figures of the number in the left-hand column
under the 4th figure at top of table is the four last
of logarithm, to which is to be prefixed the proper

...n of 4505, and what of .04505?

553 695, and of $.04505 = \bar{2}.653\,695$.

When the Number consists of Five Figures.

RULE.—Find the logarithm of the number composed of the first four figures as ɪreceding, then take the tabular difference from the right-hand column under D ɪnd multiply it by the fifth figure; reject the right-hand figure of the product and ɪdd the other figures, which are, and are termed, a proportional part to the logarithm ɔund as above, observing that the right-hand figure of the proportional part is to e added to that of the logarithm, and the rest in order.

EXAMPLE.—Required logarithm of 83 407?

NOTE.—When the number consists of less than 4 figures conceive a cipher annexed to make it four.

Log. of 8340 (83 407) = 4.921 166
Tabular difference 52, which × 7 (5th figure) = 364 = 364
4.921 202 4 *logarithm.*

The difference of the numbers is nearly proportionate to the difference of their ɪgarithms.

Thus, difference between the numbers 8340 and 8341, the next in order, is 1, and ɪe difference between their logarithms or tabular difference is 52.

The log. of this 1 in the 4th place is therefore 52. The correction then, for the 7 f the 5th place, which is .7 of 1 in the 4th place, is ascertained by the proportion : 52 :: .7 : 36.4.

The correction is obtained by multiplying the tabular difference by 7, rejecting ɪe right hand figure of the product, if the log. is to be confined to six decimal aces.

When the Number consists of any Number over Four Figures.

RULE.—Proceed as for four figures for the first four, multiplying the tabular difrence by the excess of figures over 4 and rejecting one right-hand figure of the ·oduct for a number of five figures, and two for one of six, and so on.

EXAMPLE 1.—Required logarithm of 834 079?

Log. of 8340 (834 079) = 5.921 166
Tabular difference 52, which × 79 = 4108
5.921 207 08 *logarithm.*

2.—Required logarithm of 8 340 794?

Log. of 8340 (8 340 794) = 6.921 166
b. diff. 52, which × 794 (5th, 6th, and 7th figures) = 41 288
6.921 207 288 ***logarithm.***

Or, Mantissa of 8340		=	.921 166
" "	7	(5th figure) × 52 tab. dif. =	364
" "	9	(6th ") × 52 " " =	468
" "	4	(7th ") × 52 " " =	208
Log. with *index* for 7 figures		....	6.921 207 288

To Ascertain Logarithm of a Mixed Number.

ʀULE.—Take out logarithm of the number as if it were an integer or whole num-:, to which prefix the *index* of the integral part of the number.

ɛXAMPLE.—What is logarithm of 834.0794?

Mantissa of log. of 834.0794 = 9 212 073; hence log. of 834.0794 = 2.921 207 3.

To Ascertain Logarithm of a Decimal Fraction.

ʀULE.—Take logarithm from table as if the figures were all integers, and prefix *lex* as by previous rules.

ɛXAMPLE.—Logarithm of .1234 = $\bar{1}$.091 305.

To Ascertain Logarithm of a Vulg

ʀULE.—Reduce the fraction to a decimal, and proceed as tract logarithm of denominator from that of numerator, e logarithm required.

ɛXAMPLE.—Logarithm of $\frac{3}{16}$?

$\frac{3}{16}$ = .1875. Log. .1875 = $\bar{1}$.273 001 *logarithm*
Or, Log. 3 = .477 121
" 16 = 1.204 12
$\bar{1}$.273 001 *logarithm.*

To Ascertain the Number Corresponding to a Given Logarithm.

When the given or exact Logarithm is in the Table.

Operation.—Opposite to first two figures of logarithm, neglecting the *index*, in column o, look for the remaining figures of the log. in that column or in any of the nine at the right thereof; the first three figures of the number will be found at the left in column under No., and the fourth at top directly over the log.

The number is to be made to correspond to *index* of logarithm, by pointing off decimals or prefixing ciphers.

Illustration.—What is number corresponding to log. 3.963 977?

Opposite to 963 977, in page 329, is 920, and at top of column is 4; hence, number = 9204.

When the given or exact Logarithm is not in the Table.

Operation.—Take the number for the next less logarithm from table, which will give first four figures of required number.

To ascertain the other figures, subtract the logarithm in table from the given logarithm, add ciphers, and divide by the difference in column D opposite the logarithm. Annex quotient to the four figures already ascertained, and place decimal point.

Illustration 1.—What is number corresponding to log. 5.921 207?

Given log. = 5.921 207
Next less in table 5.921 166   834 0
D = 52) 4100 (78+   78
364   834 078
460
416
44

Hence, number = 834 078.

2.—What is number corresponding to log. 3.922 853?

Given log. = 3.922 853
Next less in table 3.922 829   837 2
D = 52) 2400 (46 +   46
208   837 246
320
312
8

Hence, number = 8372.46.

Multiplication.

Rule.—Add together the logarithms of the numbers and the sum will give the logarithm of the product.

Example 1.—Multiply 345.7 by 2.581.

Log. 345.7 = 2.538 699
" 2.581 = .411 788
2.950 487 *log. of product.* Number = 892.251.

ultiply .039 02, 59.71, and .003 147.

39 02 = $\bar{2}$.591 287
= 1.776 047
147 = $\bar{3}$.497 897
$\bar{3}$.865 231 *log. of product.* Number = .007 332 15.

Division.

hm of dividend subtract that of divisor, and remainder will
tient.

uotient. Number = 7.091 85.

Rule of Three, or Proportion.

Rule.—Add together the logarithms of the second and third terms, from their sum subtract logarithm of the first, and the remainder will give logarithm of the fourth term.

Or, instead of subtracting logarithm of first term, add its *Arithmetical Complement*, and subtract 10 from its index.

Example 1.—What is fourth proportional to 723.4, .025 19, and 3574?

As 723.4	log. =		2.859 379
Is to .025 19	" =	$\bar{2}$.401 228	
So is 3574	" =	3.553 155	
		1.954 383	
First term	"	2.859 379	
		$\bar{1}$.095 004 *log. of 4th term.* Number = .124 453.	

By Arithmetical Complement.

Illustration.—As 723.4 log. = 2.859 379, Ar. com. = 7.140 621
Is to .025 19 " = $\bar{2}$.401 228
So is 3574 " = 3.553 155
$\bar{1}$.095 004 *log. of 4th term*

Number = .124 453.

2.—If an engine of 67 HP can raise 57 600 cube feet of water in a given time, what HP is required to raise 8 575 000 cube feet in like time?

Log. 8 575 000 = 6.933 234
" 67 = 1.826 075
8.759 309
" 57 600 = 4.760 422
3.998 877 *log. of 4th term.* Number = 9974.4 HP.

3.—If 14 men in 47 days excavate 5631 cube yards, what time will it require to excavate 47 280 at same rate of excavation? 394.626 *days.*

Involution.

Rule.—Multiply logarithm of given number by exponent of the power to which it is to be raised, and the product will give the logarithm of the required power.

Example.—What is cube of 30.71?

Log. 30.71 = 1.487 28
3
4.461 84 *log. of power.* Number = 28 962.73.

Evolution.

Rule.—Divide logarithm of given number by exponent of the root which is to be extracted, and quotient will give logarithm of required root.

Example 1.—What is cube root of 1234?

Log. 1234 = 3.091 315
Divide by 3 = 1.030 438 *log. of root.* Number = 10.726 01.

2.—What is 4th root of .007 654?

Log. .007 654 = $\bar{3}$.883 888

Divide by 4 (here $\bar{3} + \bar{1} + 1$) = $\bar{1}$.470 972 *log. of root.* Number = .295 78.

To Ascertain Reciprocal of a Number.

Rule.—Subtract decimal of logarithm of the number from .000 000; add 1 to index of logarithm and change its sign. The result is logarithm of the reciprocal.

Example.—Required reciprocal of 230?

.000 000
Log. 230 = 2.361 728
$\bar{3}$.638 272 = log. of .004 348 **reciprocal.**

Simple Interest.

RULE.—Add together logarithm of principal, rate per cent., and time in years, from the sum subtract 2, and the remainder will give logarithm of the interest.

EXAMPLE.—What is interest on $500, @ 6 per cent., for 3 years?

$$
\begin{aligned}
\text{Log. } 500 &= 2.69897 \\
6 &= .778151 \\
3 &= \underline{.477121} \\
& \quad 3.954242 \\
& \quad \underline{2} \\
& \quad 1.954242 \textit{ log. of interest.} \quad \text{Number} = 90 \textit{ dollars.}
\end{aligned}
$$

Compound Interest.

RULE.—Compute amount of $1 or £1, etc., at the given rate of interest for one year for the first term, which is termed the *ratio*.

Multiply logarithm of *ratio* by the time, add to product logarithm of the principal, and sum is logarithm of the amount.

Logarithms of Ratios at given Rates Per Cent.

Rate.	Log. of Ratio.	Rate.	Log. of Ratio.	Rate.	Log. of Ratio.	Rate.	Log. of Ratio.
1	.004 321 4	3.25	.013 890 1	5.5	.023 252 5	7.75	.032 4:7 3
1.25	.005 395	3.5	.014 940 3	5.75	.024 280 4	8	.033 423 8
1.5	.006 466	3.75	.015 988 1	6	.025 305 9	8.25	.034 427 9
1.75	.007 534 4	4	.017 033 3	6.25	.026 328 9	8.5	.035 429 7
2	.008 600 2	4.25	.018 076 1	6.5	.027 349 6	8.75	.036 429 3
2.25	.009 663 3	4.5	.019 116 3	6.75	.028 763 9	9	.037 426 5
2.5	.010 723 9	4.75	.020 154	7	.029 383 8	9.25	.038 421 4
2.75	.011 781 8	5	.021 189 3	7.25	.030 397 3	9.5	.039 414 1
3	.012 837 2	5.25	.022 222 1	7.5	.031 408 5	9.75	.040 404 5

EXAMPLE.—What will $364, at 6 per cent. per annum, compounded yearly, amount to in 23 years?

Log. of ratio from above table .025 3059
23
.582 0357
" " 364 2.561 101
3.143 1367 *log. of amount.* Number = 1390.39 *doll.*

Miscellaneous Illustrations.

1. What is area and circumference of a circle of 21.72 feet in diameter?

$$
\begin{aligned}
\text{Log. of } 21.72 \quad & 1.336860 \\
& \underline{2} \\
\text{Log. of } 21.72^2 &= 2.673720 \\
\text{" " } .7854 &= \underline{\bar{1}.895091} \\
\text{" " } \quad & 2.568811 = 370.54 \textit{ feet area.}
\end{aligned}
$$

$$
\begin{aligned}
\text{Log. of } 21.72 &= 1.33686 \\
\text{" " } 3.1416 &= \underline{.49715} \\
\text{" " } \quad & 1.83401 = 68.236 \textit{ feet circum.}
\end{aligned}
$$

-gle are 564, 373, and 747 feet; what is its area?

$$\frac{564 + 373 + 747}{2} = 2.925312$$

$$
\begin{aligned}
a &= 842 - 564 = 2.444045 \\
b &= 842 - 373 = 2.671173 \\
c &= 842 - 747 = \underline{1.977724} \\
& \qquad 2\overline{)10.018254} \\
= \text{Number of } & \qquad 5.009127 = 102120.4 \textit{ feet.}
\end{aligned}
$$

6?

= 3.6 × .90309 = 3.251124. Number = 1782.89.

Logarithms of Numbers.

From 1 *to* 10 000.

Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
.0	26	1.414 973	51	1.707 57	76	1.880 814
.301 03	27	1.431 364	52	1.716 003	77	1.886 491
.477 121	28	1.447 158	53	1.724 276	78	1.892 095
.602 06	29	1.462 398	54	1.732 394	79	1.897 627
.698 97	30	1.477 121	55	1.740 363	80	1.903 09
.778 151	31	1.491 362	56	1.748 188	81	1.908 485
.845 098	32	1.505 15	57	1.755 875	82	1.913 814
.903 09	33	1.518 514	58	1.763 428	83	1.919 078
.954 243	34	1.531 479	59	1.770 852	84	1.924 279
1	35	1.544 068	60	1.778 151	85	1.929 419
1.041 393	36	1.556 303	61	1.785 33	86	1.934 498
1.079 181	37	1.568 202	62	1.792 392	87	1.939 519
1.113 943	38	1.579 784	63	1.799 341	88	1.944 483
1.146 128	39	1.591 065	64	1.806 18	89	1.949 39
1.176 091	40	1.602 06	65	1.812 913	90	1.954 243
1.204 12	41	1.612 784	66	1.819 544	91	1.959 041
1.230 449	42	1.623 249	67	1.826 075	92	1.963 788
1.255 273	43	1.633 468	68	1.832 509	93	1.968 483
1.278 754	44	1.643 453	69	1.838 849	94	1.973 128
1.301 03	45	1.653 213	70	1.845 098	95	1.977 724
1.322 219	46	1.662 758	71	1.851 258	96	1.982 271
1.342 423	47	1.672 098	72	1.857 332	97	1.986 772
1.361 728	48	1.681 241	73	1.863 323	98	1.991 226
1.380 211	49	1.690 196	74	1.869 232	99	1.995 635
1.397 94	50	1.698 97	75	1.875 061	100	2

	0	1	2	3	4	5	6	7	8	9	D
00-	0000	0434	0868	1301	1734	2166	2598	3029	3461	3891	432
00-	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
00-	86	9026	9451	9876	—	—	—	—	—	—	425
01-	—	—	—	—	03	0724	1147	157	1993	2415	
01-	2837	3259	368	41	4521	494	536	5779	6197	661[illegible]	
01-	7033	7451	7868	8284	87	9116	9532	9947	—	—	
02-	—	—	—	—	—	—	—	—	0361	077[illegible]	
02-	1189	1603	2016	2428	2841	3252	3664	4075	4486	489[illegible]	
02-	5306	5715	6125	6533	6942	735	7757	8164	8571	8978	
02-	9384	9789	—	—	—	—	—	—	—	—	
03-	—	—	0195	06	1004	1408	1812	2216	2619	3021	
03-	3424	3826	4227	4628	5029	543	583	623	6629	7028	
03-	7426	7825	8223	862	9017	9414	9811	—	—	—	
04-	—	—	—	—	—	—	—	020[illegible]	[illegible]		
04-	1393	1787	2182	2576	2969	3362	3755				
04-	5323	5714	6105	6495	6885	7275	7664				
04-	9218	9606	9993	—	—	—	—				
05-	—	—	—	038	0766	1153	1538				
05-	3078	3463	3846	423	4613	4996	5378				
05-	6905	7286	7666	8046	8426	8805	9185				
06-	—	—	—	—	—	—	—				
	0	*1*	*2*	*3*	*4*	5	6				

No.		0	1	2	3	4	5	6	7	8	9
115	06-	0698	1075	1452	1829	2206	2582	2958	3333	3709	4083
116	06-	4458	4832	5206	558	5953	6326	6699	7071	7443	7815
117	06-	8186	8557	8928	9298	9668	—	—	—	—	—
117	07-	—	—	—	—	—	0038	0407	0776	1145	1514
118	07-	1882	225	2617	2985	3352	3718	4085	4451	4816	5182
119	07-	5547	5912	6276	664	7004	7368	7731	8094	8457	8819
120	07-	9181	9543	9904	—	—	—	—	—	—	—
120	08-	—	—	—	0266	0626	0987	1347	1707	2067	2426
121	08-	2785	3144	3503	3861	4219	4576	4934	5291	5647	6004
122	08-	636	6716	7071	7426	7781	8136	849	8845	9198	9552
123	08-	9905	—	—	—	—	—	—	—	—	—
123	09-	—	0258	0611	0963	1315	1667	2018	237	2721	3071
124	09-	3422	3772	4122	4471	482	5169	5518	5866	6215	6562
125	09-	691	7257	7604	7951	8298	8644	899	9335	9681	—
125	10-	—	—	—	—	—	—	—	—	—	0026
126	10-	0371	0715	1059	1403	1747	2091	2434	2777	3119	3462
127	10-	3804	4146	4487	4828	5169	551	5851	6191	6531	6871
128	10-	721	7549	7888	8227	8565	8903	9241	9579	9916	—
128	11-	—	—	—	—	—	—	—	—	—	0253
129	11-	059	0926	1263	1599	1934	227	2605	294	3275	3609
130	11-	3943	4277	4611	4944	5278	5611	5943	6276	6608	694
131	11-	7271	7603	7934	8265	8595	8926	9256	9586	9915	—
131	12-	—	—	—	—	—	—	—	—	—	0245
132	12-	0574	0903	1231	156	1888	2216	2544	2871	3198	3525
133	12-	3852	4178	4504	483	5156	5481	5806	6131	6456	6781
134	12-	7105	7429	7753	8076	8399	8722	9045	9368	969	—
134	13-	—	—	—	—	—	—	—	—	—	0012
135	13-	0334	0655	0977	1298	1619	1939	226	258	29	3219
136	13-	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403
137	13-	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564
138	13-	9879	—	—	—	—	—	—	—	—	—
138	14-	—	0194	0508	0822	1136	145	1763	2076	2389	2702
139	14-	3015	3327	3639	3951	4263	4574	4885	5196	5507	5818
140	14-	6128	6438	6748	7058	7367	7676	7985	8294	8603	8911
141	14-	9219	9527	9835	—	—	—	—	—	—	—
141	15-	—	—	—	0142	0449	0756	1063	137	1676	1982
142	15-	2288	2594	29	3205	351	3815	412	4424	4728	5032
143	15-	5336	564	5943	6246	6549	6852	7154	7457	7759	8061
144	15-	8362	8664	8965	9266	9567	9868	—	—	—	—
144	16-	—	—	—	—	—	—	0168	0469	0769	1068
145	16-	1368	1667	1967	2266	2564	2863	3161	346	3758	4055
146	16-	4353	465	4947	5244	5541	5838	6134	643	6726	7022
147	16-	7317	7613	7908	8203	8497	8792	9086	938	9674	9968
148	17-	0262	0555	0848	1141	1434	1726	2019	2311	2603	2895
149	17-	3186	3478	3769	406	4351	4641	4932	5222	5512	5802
150	17-	6091	6381	667	6959	7248	7536	7825	8113	8401	8689
151	17-	8977	9264	9552	9839	—	—	—	—	—	—
151	18-	—	—	—	—	0126	0413	0699	0986	1272	1558
152	18-	1844	2129	2415	27	2985	327	3555	3839	4123	4407
153	*18-*	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239
154	*18-*	7521	7803	8084	8366	8647	8928	9209	949	9771	—
154	*19-*	—	—	—	—	—	—	—	—	—	0051
No.		0	1	2	3	4	5	6	7	8	9

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19-	0332	0612	0892	1171	1451	173	201	2289	2567	2846	279
19-	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
19-	59	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
19-	8657	8932	9206	9481	9755	—	—	—	—	—	275
20-	—	—	—	—	—	0029	0303	0577	085	1124	274
20-	1397	167	1943	2216	2488	2761	3033	3305	3577	3848	272
20-	412	4391	4663	4934	5204	5475	5746	6016	6286	6556	271
20-	6826	7096	7365	7634	7904	8173	8441	871	8979	9247	269
20-	9515	9783	—	—	—	—	—	—	—	—	268
21-	—	—	0051	0319	0586	0853	1121	1388	1654	1921	267
21-	2188	2454	272	2986	3252	3518	3783	4049	4314	4579	266
21-	4844	5109	5373	5638	5902	6166	643	6694	6957	7221	264
21-	7484	7747	801	8273	8536	8798	906	9323	9585	9846	262
22-	0108	037	0631	0892	1153	1414	1675	1936	2196	2456	261
22-	2716	2976	3236	3496	3755	4015	4274	4533	4792	5051	259
22-	5309	5568	5826	6084	6342	66	6858	7115	7372	763	258
22-	7887	8144	84	8657	8913	917	9426	9682	9938	—	257
23-	—	—	—	—	—	—	—	—	—	0193	256
23-	0449	0704	096	1215	147	1724	1979	2234	2488	2742	255
23-	2996	325	3504	3757	4011	4264	4517	477	5023	5276	253
23-	5528	5781	6033	6285	6537	6789	7041	7292	7544	7795	252
23-	8046	8297	8548	8799	9049	9299	955	98	—	—	251
24-	—	—	—	—	—	—	—	—	005	03	250
24-	0549	0799	1048	1297	1546	1795	2044	2293	2541	279	249
24-	3038	3286	3534	3782	403	4277	4525	4772	5019	5266	248
24-	5513	5759	6006	6252	6499	6745	6991	7237	7482	7728	246
24-	7973	8219	8464	8709	8954	9198	9443	9687	9932	—	246
25-	—	—	—	—	—	—	—	—	—	0176	245
25-	042	0664	0908	1151	1395	1638	1881	2125	2368	261	243
25-	2853	3096	3338	358	3822	4064	4306	4548	479	5031	242
25-	5273	5514	5755	5996	6237	6477	6718	6958	7198	7439	241
25-	7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	[illegible]
26-	0071	031	0548	0787	1025	1263	1501	1739	1976	2214	
26-	2451	2688	2925	3162	3399	3636	3873	4109	4346	4582	
26-	4818	5054	529	5525	5761	5996	6232	6467	6702	6937	
26-	7172	7406	7641	7875	811	8344	8578	8812	9046	9279	
26-	9513	9746	998	—	—	—	—	—	—	—	
27-	—	—	—	0213	0446	0679	0912	1144	[illegible]	[illegible]	
27-	1842	2074	2306	2538	277	3001	3233	3464			
27-	4158	4389	462	485	5081	5311	5542	5772			
27-	6462	6692	6921	7151	738	7609	7838	8067			
27-	8754	8982	9211	9439	9667	9895	—	—			
28-	—	—	—	—	—	—	0123	0351			
28-	1033	1261	1488	1715	1942	2169	2396	2622			
28-	3301	3527	3753	3979	4205	4431	4656	4882			
28-	5557	5782	6007	6232	6456	6681	6905	713			
28-	7802	8026	8249	8473	8696	892	9143	9366	[illegible]		
29-	0035	0257	048	0702	0925	1147	1369	1591	[illegible]		
29-	2256	2478	2699	292	3141	3363	3584	3804	[illegible]		
29-	4466	4687	4907	5127	5347	5567	5787	6007	[illegible]		
29-	6665	6884	7104	7323	7542	7761	7979	8198	[illegible]		
29-	8853	9071	9289	9507	9725	9943	—	—	—		
30-	—	—	—	—	—	—	0161	0378	0595		
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No.	0	1	2	3	4	5	6	7	8	9	D
200	30- 103	1247	1464	1681	1898	2114	2331	2547	2764	298	21
201	30- 3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	21
202	30- 5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	21
203	30- 7496	771	7924	8137	8351	8564	8778	8991	9204	9417	21
204	30- 963	9843	—	—	—	—	—	—	—	—	21
204	31- —	—	0056	0268	0481	0693	0906	1118	133	1542	21
205	31- 1754	1966	2177	2389	26	2812	3023	3234	3445	3656	21
206	31- 3867	4078	4289	4499	471	492	513	534	5551	576	21
207	31- 597	618	639	6599	6809	7018	7227	7436	7646	7854	20
208	31- 8063	8272	8481	8689	8898	9106	9314	9522	973	9938	20
209	32- 0146	0354	0562	0769	0977	1184	1391	1598	1805	2012	20
210	32- 2219	2426	2633	2839	3046	3252	3458	3665	3871	4077	20
211	32- 4282	4488	4694	4899	5105	531	5516	5721	5926	6131	20
212	32- 6336	6541	6745	695	7155	7359	7563	7767	7972	8176	20
213	32- 838	8583	8787	8991	9194	9398	9601	9805	—	—	20
213	33- —	—	—	—	—	—	—	—	0008	0211	20
214	33- 0414	0617	0819	1022	1225	1427	163	1832	2034	2236	20
215	33- 2438	264	2842	3044	3246	3447	3649	385	4051	4253	20
216	33- 4454	4655	4856	5057	5257	5458	5658	5859	6059	626	20
217	33- 646	666	686	706	726	7459	7659	7858	8058	8257	20
218	33- 8456	8656	8855	9054	9253	9451	965	9849	—	—	20
218	34- —	—	—	—	—	—	—	—	0047	0246	19
219	34- 0444	0642	0841	1039	1237	1435	1632	183	2028	2225	19
220	34- 2423	262	2817	3014	3212	3409	3606	3802	3999	4196	19
221	34- 4392	4589	4785	4981	5178	5374	557	5766	5962	6157	19
222	34- 6353	6549	6744	6939	7135	733	7525	772	7915	811	19
223	34- 8305	85	8694	8889	9083	9278	9472	9666	986	—	19
223	35- —	—	—	—	—	—	—	—	—	0054	19
224	35- 0248	0442	0636	0829	1023	1216	141	1603	1796	1989	1
225	35- 2183	2375	2568	2761	2954	3147	3339	3532	3724	3916	1
226	35- 4108	4301	4493	4685	4876	5068	526	5452	5643	5834	19
227	35- 6026	6217	6408	6599	679	6981	7172	7363	7554	7744	1
228	35- 7935	8125	8316	8506	8696	8886	9076	9266	9456	9646	1
229	35- 9835	—	—	—	—	—	—	—	—	—	1
229	36- —	0025	0215	0404	0593	0783	0972	1161	135	1539	1
230	36- 1728	1917	2105	2294	2482	2671	2859	3048	3236	3424	18
231	36- 3612	38	3988	4176	4363	4551	4739	4926	5113	5301	18
232	36- 5488	5675	5862	6049	6236	6423	661	6796	6983	7169	18
233	36- 7356	7542	7729	7915	8101	8287	8473	8659	8845	903	18
234	36- 9216	9401	9587	9772	9958	—	—	—	—	—	18
235	37- —	—	—	—	—	0143	0328	0513	0698	0883	18
235	37- 1068	1253	1437	1622	1806	1991	2175	236	2544	2728	18
236	37- 2912	3096	328	3464	3647	3831	4015	4198	4382	4565	18
237	37- 4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	18
238	37- 6577	6759	6942	7124	7306	7488	767	7852	8034	8216	18
239	37- 8398	858	8761	8943	9124	9306	9487	9668	9849	—	18
239	38- —	—	—	—	—	—	—	—	—	003	18
240	38- 0211	0392	0573	0754	0934	1115	1296	1476	1656	1837	18
241	38- 2017	2197	2377	2557	2737	2917	3097	3277	3456	3636	18
242	38- 3815	3995	4174	4353	4533	4712	4891	507	5249	5428	17
243	38- 5606	5785	5964	6142	6321	6499	6677	6856	7034	7212	17
244	38- 739	7568	7746	7923	8101	8279	8456	8634	8811	8989	17
No.	0	1	2	3	4	5	6	7	8	9	

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38-	9166	9343	952	9698	9875	—	—	—	—	—	177
39-	—	—	—	—	—	0051	0228	0405	0582	0759	177
39-	0935	1112	1288	1464	1641	1817	1993	2169	2345	2521	176
39-	2697	2873	3048	3224	34	3575	3751	3926	4101	4277	176
39-	4452	4627	4802	4977	5152	5326	5501	5676	585	6025	175
39-	6199	6374	6548	6722	6896	7071	7245	7419	7592	7766	174
39-	794	8114	8287	8461	8634	8808	8981	9154	9328	9501	173
39-	9674	9847	—	—	—	—	—	—	—	—	173
40-	—	—	002	0192	0365	0538	0711	0883	1056	1228	173
40-	1401	1573	1745	1917	2089	2261	2433	2605	2777	2949	172
40-	3121	3292	3464	3635	3807	3978	4149	432	4492	4663	171
40-	4834	5005	5176	5346	5517	5688	5858	6029	6199	637	171
40-	654	671	6881	7051	7221	7391	7561	7731	7901	807	170
40-	824	841	8579	8749	8918	9087	9257	9426	9595	9764	169
40-	9933	—	—	—	—	—	—	—	—	—	169
41-	—	0102	0271	044	0609	0777	0946	1114	1283	1451	169
41-	162	1788	1956	2124	2293	2461	2629	2796	2964	3132	168
41-	33	3467	3635	3803	397	4137	4305	4472	4639	4806	167
41-	4973	514	5307	5474	5641	5808	5974	6141	6308	6474	167
41-	6641	6807	6973	7139	7306	7472	7638	7804	797	8135	166
41-	8301	8467	8633	8798	8964	9129	9295	946	9625	9791	165
41-	9956	—	—	—	—	—	—	—	—	—	165
42-	—	0121	0286	0451	0616	0781	0945	111	1275	1439	165
42-	1604	1768	1933	2097	2261	2426	259	2754	2918	3082	164
42-	3246	341	3574	3737	3901	4065	4228	4392	4555	4718	164
42-	4882	5045	5208	5371	5534	5697	586	6023	6186	6349	163
42-	6511	6674	6836	6999	7161	7324	7486	7648	7811	7973	162
42-	8135	8297	8459	8621	8783	8944	9106	9268	9429	9591	162
42-	9752	9914	—	—	—	—	—	—	—	—	162
43-	—	—	0075	0236	0398	0559	072	0881	1042	1203	161
43-	1364	1525	1685	1846	2007	2167	2328	2488	2649	2809	161
43-	2969	313	329	345	361	377	393	409	4249	4409	160
43-	4569	4729	4888	5048	5207	5367	5526	5685	5844	6004	159
43-	6163	6322	6481	664	6799	6957	7116	7275	7433	7592	159
43-	7751	7909	8067	8226	8384	8542	8701	8859	9017	9175	158
43-	9333	9491	9648	9806	9964	—	—	—	—	—	158
44-	—	—	—	—	—	0122	0279	0437	0594	0752	158
44-	0909	1066	1224	1381	1538	1695	1852	2009	2166	2323	157
44-	248	2637	2793	295	3106	3263	3419	3576	3732	3889	157
44-	4045	4201	4357	4513	4669	4825	4981	5137	5293	5449	156
44-	5604	576	5915	6071	6226	6382	6537	6692	6848	7003	155
44-	7158	7313	7468	7623	7778	7933	8088	8242	8397	8552	155
44-	8706	8861	9015	917	9324	9478	9633	9787	9941	—	154
45-	—	—	—	—	—	—	—	—	—	0095	154
45-	0249	0403	0557	0711	0865	1018	1172	1326	1479	1633	154
45-	1786	194	2093	2247	24	2553	2706	2859	3012	3165	153
45-	3318	3471	3624	3777	393	4082	4235	4387	454	4692	153
45-	4845	4997	515	5302	5454	5606	5758	591	6062	6214	152
45-	6366	6518	667	6821	6973	7125	7276	7428	7579	7731	152
45-	7882	8033	8184	8336	8487	8638	8789	894	9091	9242	151
45-	9392	9543	9694	9845	9995	—	—	—	—	—	151
46-	—	—	—	—	—	0146	0296	0447	0597	0748	151
46-	0898	1048	1198	1348	1499	1649	1799	1948	2098	2248	150
	0	1	2	3	4	5	6	7	8	9	D

No.		0	1	2	3	4	5	6	7	8	9
290	46-	2398	2548	2697	2847	2997	3146	3296	3445	3594	37
291	46-	3893	4042	4191	434	449	4639	4788	4936	5085	52
292	46-	5383	5532	568	5829	5977	6126	6274	6423	6571	67
293	46-	6868	7016	7164	7312	746	7608	7756	7904	8052	8
294	46-	8347	8495	8643	879	8938	9085	9233	938	9527	9
295	46-	9822	9969	—	—	—	—	—	—	—	-
295	47-	—	—	0116	0263	041	0557	0704	0851	0998	11
296	47-	1292	1438	1585	1732	1878	2025	2171	2318	2464	2
297	47-	2756	2903	3049	3195	3341	3487	3633	3779	3925	4
298	47-	4216	4362	4508	4653	4799	4944	509	5235	5381	5
299	47-	5671	5816	5962	6107	6252	6397	6542	6687	6832	6
300	47-	7121	7266	7411	7555	77	7844	7989	8133	8278	8
301	47-	8566	8711	8855	8999	9143	9287	9431	9575	9719	9
302	48-	0007	0151	0294	0438	0582	0725	0869	1012	1156	1
303	48-	1443	1586	1729	1872	2016	2159	2302	2445	2588	2
304	48-	2874	3016	3159	3302	3445	3587	373	3872	4015	4
305	48-	43	4442	4585	4727	4869	5011	5153	5295	5437	5
306	48-	5721	5863	6005	6147	6289	643	6572	6714	6855	6
307	48-	7138	728	7421	7563	7704	7845	7986	8127	8269	8
308	48-	8551	8692	8833	8974	9114	9255	9396	9537	9677	9
309	48-	9958	—	—	—	—	—	—	—	—	-
309	49-	—	0099	0239	038	052	0661	0801	0941	1081	1
310	49-	1362	1502	1642	1782	1922	2062	2201	2341	2481	2
311	49-	276	29	304	3179	3319	3458	3597	3737	3876	4
312	49-	4155	4294	4433	4572	4711	485	4989	5128	5267	5
313	49-	5544	5683	5822	596	6099	6238	6376	6515	6653	6
314	49-	693	7068	7206	7344	7483	7621	7759	7897	8035	8
315	49-	8311	8448	8586	8724	8862	8999	9137	9275	9412	9
316	49-	9687	9824	9962	—	—	—	—	—	—	-
316	50-	—	—	—	0099	0236	0374	0511	0648	0785	0
317	50-	1059	1196	1333	147	1607	1744	188	2017	2154	2
318	50-	2427	2564	27	2837	2973	3109	3246	3382	3518	3
319	50-	3791	3927	4063	4199	4335	4471	4607	4743	4878	5
320	50-	515	5286	5421	5557	5693	5828	5964	6099	6234	6
321	50-	6505	664	6776	6911	7046	7181	7316	7451	7586	7
322	50-	7856	7991	8126	826	8395	853	8664	8799	8934	9
323	50-	9203	9337	9471	9606	974	9874	—	—	—	-
323	51-	—	—	—	—	—	—	0009	0143	0277	0
324	51-	0545	0679	0813	0947	1081	1215	1349	1482	1616	1
325	51-	1883	2017	2151	2284	2418	2551	2684	2818	2951	3
326	51-	3218	3351	3484	3617	375	3883	4016	4149	4282	4
327	51-	4548	4681	4813	4946	5079	5211	5344	5476	5609	5
328	51-	5874	6006	6139	6271	6403	6535	6668	68	6932	7
329	51-	7196	7328	746	7592	7724	7855	7987	8119	8251	8
330	51-	8514	8646	8777	8909	904	9171	9303	9434	9566	9
331	51-	9828	9959	—	—	—	—	—	—	—	-
331	52-	—	—	009	0221	0353	0484	0615	0745	0876	1
332	52-	1138	1269	14	153	1661	1792	1922	2053	2183	2
333	52-	2444	2575	2705	2835	2966	3096	3226	3356	3486	3
334	52-	3746	3876	4006	4136	4266	4396	4526	4656	4785	4
No.		0	1	2	3	4	5	6	7	8	

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52-	5045	5174	5304	5434	5563	5693	5822	5951	6081	621	129
52-	6339	6469	6598	6727	6856	6985	7114	7243	7372	7501	129
52-	763	7759	7888	8016	8145	8274	8402	8531	866	8788	129
52-	8917	9045	9174	9302	943	9559	9687	9815	9943	—	128
53-	—	—	—	—	—	—	—	—	—	0072	128
53-	02	0328	0456	0584	0712	084	0968	1096	1223	1351	128
53-	1479	1607	1734	1862	199	2117	2245	2372	25	2627	128
53-	2754	2882	3009	3136	3264	3391	3518	3645	3772	3899	127
53-	4026	4153	428	4407	4534	4661	4787	4914	5041	5167	127
53-	5294	5421	5547	5674	58	5927	6053	618	6306	6432	126
53-	6558	6685	6811	6937	7063	7189	7315	7441	7567	7693	126
53-	7819	7945	8071	8197	8322	8448	8574	8699	8825	8951	126
53-	9076	9202	9327	9452	9578	9703	9829	9954	—	—	126
54-	—	—	—	—	—	—	—	—	0079	0204	125
54-	0329	0455	058	0705	083	0955	108	1205	133	1454	125
54-	1579	1704	1829	1953	2078	2203	2327	2452	2576	2701	125
54-	2825	295	3074	3199	3323	3447	3571	3696	382	3944	124
54-	4068	4192	4316	444	4564	4688	4812	4936	506	5183	124
54-	5307	5431	5555	5678	5802	5925	6049	6172	6296	6419	124
54-	6543	6666	6789	6913	7036	7159	7282	7405	7529	7652	123
54-	7775	7898	8021	8144	8267	8389	8512	8635	8758	8881	123
54-	9003	9126	9249	9371	9494	9616	9739	9861	9984	—	123
55-	—	—	—	—	—	—	—	—	—	0106	123
55-	0228	0351	0473	0595	0717	084	0962	1084	1206	1328	122
55-	145	1572	1694	1816	1938	206	2181	2303	2425	2547	122
55-	2668	279	2911	3033	3155	3276	3398	3519	364	3762	121
55-	3883	4004	4126	4247	4368	4489	461	4731	4852	4973	121
55-	5094	5215	5336	5457	5578	5699	582	594	6061	6182	121
55-	6303	6423	6544	6664	6785	6905	7026	7146	7267	7387	120
55-	7507	7627	7748	7868	7988	8108	8228	8349	8469	8589	120
55-	8709	8829	8948	9068	9188	9308	9428	9548	9667	9787	120
55-	9907	—	—	—	—	—	—	—	—	—	120
56-	—	0026	0146	0265	0385	0504	0624	0743	0863	0982	119
56-	1101	1221	134	1459	1578	1698	1817	1936	2055	2174	119
56-	2293	2412	2531	265	2769	2887	3006	3125	3244	3362	119
56-	3481	36	3718	3837	3955	4074	4192	4311	4429	4548	119
56-	4666	4784	4903	5021	5139	5257	5376	5494	5612	573	118
56-	5848	5966	6084	6202	632	6437	6555	6673	6791	6909	118
56-	7026	7144	7262	7379	7497	7614	7732	7849	7967	8084	118
56-	8202	8319	8436	8554	8671	8788	8905	9023	914	9257	117
56-	9374	9491	9608	9725	9842	9959	—	—	—	—	117
57-	—	—	—	—	—	—	0076	0193	0309	0426	117
57-	0543	066	0776	0893	101	1126	1243	1359	1476	1592	117
57-	1709	1825	1942	2058	2174	2291	2407	2523	2639	2755	116
57-	2872	2988	3104	322	3336	3452	3568	3684	38	3915	116
7-	4031	4147	4263	4379	4494	461	4726	4841	4957	5072	116
7-	5188	5303	5419	5534	565	5765	588	5996	6111	6226	115
7-	6341	6457	6572	6687	6802	6917	7032	7147	7262	7377	115
7-	7492	7607	7722	7836	7951	8066	8181	8295	841	8525	115
7-	8639	8754	8868	8983	9097	9212	9326	9441	9555	9669	114
	0	1	2	3	4	5	6	7	8	9	D

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No.		0	1	2	3	4	5	6	7	8	9	D
200	30-	103	1247	1464	1681	1898	2114	2331	2547	2764	298	217
201	30-	3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	216
202	30-	5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	215
203	30-	7496	771	7924	8137	8351	8564	8778	8991	9204	9417	213
204	30-	963	9843	—	—	—	—	—	—	—	—	213
204	31-	—	—	0056	0268	0481	0693	0906	1118	133	1542	212
205	31-	1754	1966	2177	2389	26	2812	3023	3234	3445	3656	211
206	31-	3867	4078	4289	4499	471	492	513	534	5551	576	210
207	31-	597	618	639	6599	6809	7018	7227	7436	7646	7854	209
208	31-	8063	8272	8481	8689	8898	9106	9314	9522	973	9938	208
209	32-	0146	0354	0562	0769	0977	1184	1391	1598	1805	2012	207
210	32-	2219	2426	2633	2839	3046	3252	3458	3665	3871	4077	206
211	32-	4282	4488	4694	4899	5105	531	5516	5721	5926	6131	205
212	32-	6336	6541	6745	695	7155	7359	7563	7767	7972	8176	204
213	32-	838	8583	8787	8991	9194	9398	9601	9805	—	—	204
213	33-	—	—	—	—	—	—	—	—	0008	0211	203
214	33-	0414	0617	0819	1022	1225	1427	163	1832	2034	2236	202
215	33-	2438	264	2842	3044	3246	3447	3649	385	4051	4253	202
216	33-	4454	4655	4856	5057	5257	5458	5658	5859	6059	626	201
217	33-	646	666	686	706	726	7459	7659	7858	8058	8257	200
218	33-	8456	8656	8855	9054	9253	9451	965	9849	—	—	200
218	34-	—	—	—	—	—	—	—	—	0047	0246	199
219	34-	0444	0642	0841	1039	1237	1435	1632	183	2028	2225	198
220	34-	2423	262	2817	3014	3212	3409	3606	3802	3999	4196	197
221	34-	4392	4589	4785	4981	5178	5374	557	5766	5962	6157	196
222	34-	6353	6549	6744	6939	7135	733	7525	772	7915	811	195
223	34-	8305	85	8694	8889	9083	9278	9472	9666	986	—	194
223	35-	—	—	—	—	—	—	—	—	—	0054	194
224	35-	0248	0442	0636	0829	1023	1216	141	1603	1796	1989	193
225	35-	2183	2375	2568	2761	2954	3147	3339	3532	3724	3916	193
226	35-	4108	4301	4493	4685	4876	5068	526	5452	5643	5834	192
227	35-	6026	6217	6408	6599	679	6981	7172	7363	7554	7744	191
228	35-	7935	8125	8316	8506	8696	8886	9076	9266	9456	9646	190
229	35-	9835	—	—	—	—	—	—	—	—	—	189
229	36-	—	0025	0215	0404	0593	0783	0972	1161	135	1539	189
230	36-	1728	1917	2105	2294	2482	2671	2859	3048	3236	3424	188
231	36-	3612	38	3988	4176	4363	4551	4739	4926	5113	5301	188
232	36-	5488	5675	5862	6049	6236	6423	661	6796	6983	7169	187
[illegible]	36-	7356	7542	7729	7915	8101	8287	8473	8659	8845	903	186
[illegible]	36-	9216	9401	9587	9772	9958	—	—	—	—	—	186
[illegible]	[illegible]	—	—	—	—	—	0143	0328	0513	0698	0883	185
[illegible]	[illegible]	1068	1253	1437	1622	1806	1991	2175	236	2544	2728	184
[illegible]	[illegible]	2912	3096	328	3464	3647	3831	4015	4198	4382	4565	184
[illegible]	[illegible]	4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	183
[illegible]	[illegible]	[illegible]	6759	6942	7124	7306	7488	767	7852	8034	8216	182
[illegible]	[illegible]	[illegible]	[illegible]	8761	8943	[illegible]	[illegible]	9487	9668	9849	—	182
[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	—	—	—	003	181
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1296	1476	1656	1837	181
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3097	3277	3456	3636	180
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4891	507	5249	5428	179
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6499	6677	6856	7034	7212	178
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8279	8456	8634	8811	8989	178
						[illegible]	5	6	7	8	9	D

No.	0	1	2	3	4	5	6	7	8	9	D
45	38- 9166	9343	952	9698	9875	—	—	—	—	—	177
45	39- —	—	—	—	—	0051	0228	0405	0582	0759	177
46	39- 0935	1112	1288	1464	1641	1817	1993	2169	2345	2521	176
47	39- 2697	2873	3048	3224	34	3575	3751	3926	4101	4277	176
48	39- 4452	4627	4802	4977	5152	5326	5501	5676	585	6025	175
49	39- 6199	6374	6548	6722	6896	7071	7245	7419	7592	7766	174
50	39- 794	8114	8287	8461	8634	8808	8981	9154	9328	9501	173
51	39- 9674	9847	—	—	—	—	—	—	—	—	173
51	40- —	—	002	0192	0365	0538	0711	0883	1056	1228	173
52	40- 1401	1573	1745	1917	2089	2261	2433	2605	2777	2949	172
53	40- 3121	3292	3464	3635	3807	3978	4149	432	4492	4663	171
54	40- 4834	5005	5176	5346	5517	5688	5858	6029	6199	637	171
55	40- 654	671	6881	7051	7221	7391	7561	7731	7901	807	170
56	40- 824	841	8579	8749	8918	9087	9257	9426	9595	9764	169
57	40- 9933	—	—	—	—	—	—	—	—	—	169
57	41- —	0102	0271	044	0609	0777	0946	1114	1283	1451	169
58	41- 162	1788	1956	2124	2293	2461	2629	2796	2964	3132	168
59	41- 33	3467	3635	3803	397	4137	4305	4472	4639	4806	167
60	41- 4973	514	5307	5474	5641	5808	5974	6141	6308	6474	167
61	41- 6641	6807	6973	7139	7306	7472	7638	7804	797	8135	166
62	41- 8301	8467	8633	8798	8964	9129	9295	946	9625	9791	165
63	41- 9956	—	—	—	—	—	—	—	—	—	165
63	42- —	0121	0286	0451	0616	0781	0945	111	1275	1439	165
64	42- 1604	1768	1933	2097	2261	2426	259	2754	2918	3082	164
65	42- 3246	341	3574	3737	3901	4065	4228	4392	4555	4718	164
66	42- 4882	5045	5208	5371	5534	5697	586	6023	6186	6349	163
67	42- 6511	6674	6836	6999	7161	7324	7486	7648	7811	7973	162
68	42- 8135	8297	8459	8621	8783	8944	9106	9268	9429	9591	162
69	42- 9752	9914	—	—	—	—	—	—	—	—	162
69	43- —	—	0075	0236	0398	0559	072	0881	1042	1203	161
70	43- 1364	1525	1685	1846	2007	2167	2328	2488	2649	2809	161
71	43- 2969	313	329	345	361	377	393	409	4249	4409	160
72	43- 4569	4729	4888	5048	5207	5367	5526	5685	5844	6004	159
73	43- 6163	6322	6481	664	6799	6957	7116	7275	7433	7592	159
74	43- 7751	7909	8067	8226	8384	8542	8701	8859	9017	9175	158
75	43- 9333	9491	9648	9806	9964	—	—	—	—	—	15[illegible]
75	44- —	—	—	—	—	0122	0279	0437	0594	0752	[illegible]
76	44- 0909	1066	1224	1381	1538	1695	1852	[illegible]	[illegible]	2323	[illegible]
77	44- 248	2637	2793	295	3106	3263	3419	[illegible]			
78	44- 4045	4201	4357	4513	4669	4825	4981	[illegible]			
79	44- 5604	576	5915	6071	6226	6382	6537	[illegible]			
80	44- 7158	7313	7468	7623	7778	7933	8088	[illegible]			
81	44- 8706	8861	9015	917	9324	9478	9633	[illegible]			
81	45- —	—	—	—	—	—	—	—			
82	45- 0249	0403	0557	0711	0865	1018	1172	13			
83	45- 1786	194	2093	2247	24	2553	2706	28			
84	45- 3318	3471	3624	3777	393	4082	4235	438			
85	45- 4845	4997	515	5302	5454	5606	5758	591			
86	45- 6366	6518	667	6821	6973	7125	7276	7428			
87	45- 7882	8033	8184	8336	8487	8638	8789	894			
88	45- 9392	9543	9694	9845	9995	—	—	—			
88	46- —	—	—	—	—	0146	0296	0447	05		
89	46- 0898	1048	1198	1348	1499	1649	1799	1948	20		
N	0	1	2	3	4	5	6	7	8		

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[illegible]	4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4[illegible]	[illegible]	[illegible]	—	—	—	—	—	—	—	[illegible]
[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
305	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
306	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
307	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
308	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
309	48	[illegible]	—	—	—	—	—	—	—	—	[illegible]
309	49	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
310	49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
311	49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
312	49	4155	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
313	49	5544	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
314	49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	49	8311	8448	8586	8724	8862	8999	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	49	9687	9824	9962	—	—	—	—	—	—	[illegible]
[illegible]	50	—	—	—	0099	0236	0374	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	50	1059	1196	1333	147	1607	1744	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	50	2427	2564	27	2837	2973	3109	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	3791	3927	4063	4199	4335	4471	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	50	515	5286	5421	5557	5693	5828	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	50	6505	664	6776	6911	7046	7181	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	50	7856	7991	8126	826	8395	853	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	50	9203	9337	9471	9606	974	[illegible]	—	—	—	[illegible]
[illegible]	[illegible]	—	—	—	—	—	—	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	51	0545	0679	0812	0947	1081	1215	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1883	2017	[illegible]	[illegible]	2418	2551	[illegible]	[illegible]	[illegible]	3084
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3885	[illegible]	[illegible]	[illegible]	4415
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5079	5211	[illegible]	[illegible]	[illegible]	5741
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]03	6535	[illegible]	[illegible]	[illegible]	7064
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]24	7851	[illegible]	[illegible]	[illegible]	8382
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]04	9171	[illegible]	[illegible]	[illegible]	9697
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0353	[illegible]	[illegible]	[illegible]	[illegible]	1007
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1661	[illegible]	[illegible]	[illegible]	[illegible]	2314
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2966	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4266	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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71-	1807	1892	1976	206	2144	2229	2313	2397	2481	2566	84
71-	265	2734	2818	2902	2986	307	3154	3238	3323	3407	84
71-	3491	3575	3659	3742	3826	391	3994	4078	4162	4246	84
71-	433	4414	4497	4581	4665	4749	4833	4916	5	5084	84
71-	5167	5251	5335	5418	5502	5586	5669	5753	5836	592	84
71-	6003	6087	617	6254	6337	6421	6504	6588	6671	6754	83
71-	6838	6921	7004	7088	7171	7254	7338	7421	7504	7587	83
71-	7671	7754	7837	792	8003	8086	8169	8253	8336	8419	83
71-	8502	8585	8668	8751	8834	8917	9	9083	9165	9248	83
71-	9331	9414	9497	958	9663	9745	9828	9911	9994	—	83
72-	—	—	—	—	—	—	—	—	—	0077	83
72-	0159	0242	0325	0407	049	0573	0655	0738	0821	0903	83
72-	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	82
72-	1811	1893	1975	2058	214	2222	2305	2387	2469	2552	82
72-	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	82
72-	3456	3538	362	3702	3784	3866	3948	403	4112	4194	82
72-	4276	4358	444	4522	4604	4685	4767	4849	4931	5013	82
72-	5095	5176	5258	534	5422	5503	5585	5667	5748	583	82
72-	5912	5993	6075	6156	6238	632	6401	6483	6564	6646	82
72-	6727	6809	689	6972	7053	7134	7216	7297	7379	746	81
72-	7541	7623	7704	7785	7866	7948	8029	811	8191	8273	81
72-	8354	8435	8516	8597	8678	8759	8841	8922	9003	9084	81
72-	9165	9246	9327	9408	9489	957	9651	9732	9813	9893	81
72-	9974	—	—	—	—	—	—	—	—	—	81
73-	—	0055	0136	0217	0298	0378	0459	054	0621	0702	81
73-	0782	0863	0944	1024	1105	1186	1266	1347	1428	1508	81
73-	1589	1669	175	183	1911	1991	2072	2152	2233	2313	81
73-	2394	2474	2555	2635	2715	2796	2876	2956	3037	3117	80
73-	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	80
73-	3999	4079	416	424	432	44	448	456	464	472	80
73-	48	488	496	504	512	52	5279	5359	5439	5519	80
73-	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	80
73-	6397	6476	6556	6635	6715	6795	6874	6954	7034	7113	80
73-	7193	7272	7352	7431	7511	759	767	7749	7829	7908	79
73-	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	79
73-	8781	886	8939	9018	9097	9177	9256	9335	9414	9493	79
73-	9572	9651	9731	981	9889	9968	—	—	—	—	79
74-	—	—	—	—	—	—	0047	0126	0205	0284	79
74-	0363	0442	0521	06	0678	0757	0836	0915	0994	1073	79
74-	1152	123	1309	1388	1467	1546	1624	1703	1782	186	79
74-	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	79
74-	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	78
74-	351	3588	3667	3745	3823	3902	398	4058	4136	4215	78
74-	4293	4371	4449	4528	4606	4684	4762	484	4919	4997	78
74-	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
74-	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	78
74-	6634	6712	679	6868	6945	7023	7101	7179	7256	7334	78
74-	7412	7489	7567	7645	7722	78	7878	7955	8033	811	78
	0	*1*	*2*	*3*	*4*	5	6	7	8	9	D

No.		0	1	2	3	4	5	6	7	8	9
560	74-	8188	8266	8343	8421	8498	8576	8653	8731	8808	8885
561	74-	8963	904	9118	9195	9272	935	9427	9504	9582	9659
562	74-	9736	9814	9891	9968	—	—	—	—	—	—
562	75-	—	—	—	—	0045	0123	02	0277	0354	0431
563	75-	0508	0586	0663	074	0817	0894	0971	1048	1125	1202
564	75-	1279	1356	1433	151	1587	1664	1741	1818	1895	1972
565	75-	2048	2125	2202	2279	2356	2433	2509	2586	2663	274
566	75-	2816	2893	297	3047	3123	32	3277	3353	343	3506
567	75-	3583	366	3736	3813	3889	3966	4042	4119	4195	4272
568	75-	4348	4425	4501	4578	4654	473	4807	4883	496	5036
569	75-	5112	5189	5265	5341	5417	5494	557	5646	5722	5799
570	75-	5875	5951	6027	6103	618	6256	6332	6408	6484	656
571	75-	6636	6712	6788	6864	694	7016	7092	7168	7244	732
572	75-	7396	7472	7548	7624	77	7775	7851	7927	8003	8079
573	75-	8155	823	8306	8382	8458	8533	8609	8685	8761	8836
574	75-	8912	8988	9063	9139	9214	929	9366	9441	9517	9592
575	75-	9668	9743	9819	9894	997	—	—	—	—	—
575	76-	—	—	—	—	—	0045	0121	0196	0272	0347
576	76-	0422	0498	0573	0649	0724	0799	0875	095	1025	1101
577	76-	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853
578	76-	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604
579	76-	2679	2754	2829	2904	2978	3053	3128	3203	3278	3353
580	76-	3428	3503	3578	3653	3727	3802	3877	3952	4027	4101
581	76-	4176	4251	4326	44	4475	455	4624	4699	4774	4848
582	76-	4923	4998	5072	5147	5221	5296	537	5445	552	5594
583	76-	5669	5743	5818	5892	5966	6041	6115	619	6264	6338
584	76-	6413	6487	6562	6636	671	6785	6859	6933	7007	7082
585	76-	7156	723	7304	7379	7453	7527	7601	7675	7749	7823
586	76-	7898	7972	8046	812	8194	8268	8342	8416	849	8564
587	76-	8638	8712	8786	886	8934	9008	9082	9156	923	9303
588	76-	9377	9451	9525	9599	9673	9746	982	9894	9968	—
588	77-	—	—	—	—	—	—	—	—	—	0042
589	77-	0115	0189	0263	0336	041	0484	0557	0631	0705	0778
590	77-	0852	0926	0999	1073	1146	122	1293	1367	144	1514
591	77-	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248
592	77-	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981
593	77-	3055	3128	3201	3274	3348	3421	3494	3567	364	3713
594	77-	3786	386	3933	4006	4079	4152	4225	4298	4371	4444
595	77-	4517	459	4663	4736	4809	4882	4955	5028	51	5173
596	77-	5246	5319	5392	5465	5538	561	5683	5756	5829	5902
597	77-	5974	6047	612	6193	6265	6338	6411	6483	6556	6629
598	77-	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354
599	77-	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079
600	77-	8151	8224	8296	8368	8441	8513	8585	8658	873	8802
601	77-	8874	8947	9019	9091	9163	9236	9308	938	9452	9524
602	77-	9596	9669	9741	9813	9885	9957	—	—	—	—
602	78-	—	—	—	—	—	—	0029	0101	0173	0245
603	78-	0317	0389	0461	0533	0605	0677	0749	0821	0893	0965
604	78-	1037	1109	1181	1253	1324	1396	1468	154	1612	1684
N.		0	1	2	3	4	5	6	7	8	9

	0	1	2	3	4	5	6	7	8	9	D
2-	8389	8491	8593	8695	8797	89	9002	9104	9206	9308	102
2-	941	9512	9613	9715	9817	9919	—	—	—	—	102
3-	—	—	—	—	—	—	0021	0123	0224	0326	102
3-	0428	053	0631	0733	0835	0936	1038	1139	1241	1342	102
3-	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	101
3-	2457	2559	266	2761	2862	2963	3064	3165	3266	3367	101
3-	3468	3569	367	3771	3872	3973	4074	4175	4276	4376	101
3-	4477	4578	4679	4779	488	4981	5081	5182	5283	5383	101
3-	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	100
3-	6488	6588	6688	6789	6889	6989	7089	7189	729	739	100
3-	749	759	769	779	789	799	809	819	829	839	100
3-	8489	8589	8689	8789	8888	8988	9088	9188	9287	9387	100
3-	9486	9586	9686	9785	9885	9984	—	—	—	—	100
4-	—	—	—	—	—	—	0084	0183	0283	0382	99
4-	0481	0581	068	0779	0879	0978	1077	1177	1276	1375	99
4-	1474	1573	1672	1771	1871	197	2069	2168	2267	2366	99
4-	2465	2563	2662	2761	286	2959	3058	3156	3255	3354	99
4-	3453	3551	365	3749	3847	3946	4044	4143	4242	434	99
4-	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	98
4-	5422	5521	5619	5717	5815	5913	6011	611	6208	6306	98
4-	6404	6502	66	6698	6796	6894	6992	7089	7187	7285	98
64-	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	98
64-	836	8458	8555	8653	875	8848	8945	9043	914	9237	97
64-	9335	9432	953	9627	9724	9821	9919	—	—	—	97
65-	—	—	—	—	—	—	—	0016	0113	021	97
65-	0308	0405	0502	0599	0696	0793	089	0987	1084	1181	97
65-	1278	1375	1472	1569	1666	1762	1859	1956	2053	215	97
65-	2246	2343	244	2536	2633	273	2826	2923	3019	3116	97
65-	3213	3309	3405	3502	3598	3695	3791	3888	3984	408	96
65-	4177	4273	4369	4465	4562	4658	4754	485	4946	5042	96
65-	5138	5235	5331	5427	5523	5619	5715	581	5906	6002	96
65-	6098	6194	629	6386	6482	6577	6673	6769	6864	696	96
65-	7056	7152	7247	7343	7438	7534	7629	7725	782	7916	96
65-	8011	8107	8202	8298	8393	8488	8584	8679	8774	887	[illegible]
65-	8965	906	9155	925	9346	9441	9536	9631	9726	9821	
65-	9916	—	—	—	—	—	—	—			
66-	—	0011	0106	0201	0296	0391	0486	0[illegible]			
66-	0865	096	1055	115	1245	1339	1434	1[illegible]			
66-	1813	1907	2002	2096	2191	2286	238	2[illegible]			
66-	2758	2852	2947	3041	3135	323	3324	3[illegible]			
66-	3701	3795	3889	3983	4078	4172	4266	43			
66-	4642	4736	483	4924	5018	5112	5206	529			
66-	5581	5675	5769	5862	5956	605	6143	623			
66-	6518	6612	6705	6799	6892	6986	7079	7173			
66-	7453	7546	764	7733	7826	792	8013	8106			
66-	8386	8479	8572	8665	8759	8852	8945	9038	[illegible]		
66-	9317	941	9503	9596	9689	9782	9875	9967	[illegible]		
7-	—	—	—	—	—	—	—	—	00[illegible]		
7-	0246	0339	0431	0524	0617	071	0802	0895	098[illegible]		
7-	1173	1265	1358	1451	1543	1636	1728	1821	1913		
	0	1	2	3	4	5	6	7	8		

No.		0	1	2	3	4	5	6	7	8	9	D
655	81-	6241	6308	6374	644	6506	6573	6639	6705	6771	6838	66
656	81-	6904	697	7036	7102	7169	7235	7301	7367	7433	7499	66
657	81-	7565	7631	7698	7764	783	7896	7962	8028	8094	816	66
658	81-	8226	8292	8358	8424	849	8556	8622	8688	8754	882	66
659	81-	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
660	81-	9544	961	9676	9741	9807	9873	9939	—	—	—	66
660	82-	—	—	—	—	—	—	—	0004	007	0136	66
661	82-	0201	0267	0333	0399	0464	053	0595	0661	0727	0792	66
662	82-	0858	0924	0989	1055	112	1186	1251	1317	1382	1448	66
663	82-	1514	1579	1645	171	1775	1841	1906	1972	2037	2103	65
664	82-	2168	2233	2299	2364	243	2495	256	2626	2691	2756	65
665	82-	2822	2887	2952	3018	3083	3148	3213	3279	3344	3409	65
666	82-	3474	3539	3605	367	3735	38	3865	393	3996	4061	65
667	82-	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	65
668	82-	4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	65
669	82-	5426	5491	5556	5621	5686	5751	5815	588	5945	601	65
670	82-	6075	614	6204	6269	6334	6399	6464	6528	6593	6658	65
671	82-	6723	6787	6852	6917	6981	7046	7111	7175	724	7305	65
672	82-	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	65
673	82-	8015	808	8144	8209	8273	8338	8402	8467	8531	8595	64
674	82-	866	8724	8789	8853	8918	8982	9046	9111	9175	9239	64
675	82-	9304	9368	9432	9497	9561	9625	969	9754	9818	9882	64
676	82-	9947	—	—	—	—	—	—	—	—	—	[illegible]
676	83-	—	0011	0075	0139	0204	0268	0332	0396	046	0525	[illegible]
677	83-	0589	0653	0717	0781	0845	0909	0973	1037	1102	1166	[illegible]
678	83-	123	1294	1358	1422	1486	155	1614	1678	1742	1806	[illegible]
679	83-	187	1934	1998	2062	2126	2189	2253	2317	2381	2445	[illegible]
680	83-	2509	2573	2637	27	2764	2828	2892	2956	302	3083	[illegible]
681	83-	3147	3211	3275	3338	3402	3466	353	3593	3657	3721	[illegible]
682	83-	3784	3848	3912	3975	4039	4103	4166	423	4294	4357	[illegible]
683	83-	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	[illegible]
684	83-	5056	512	5183	5247	531	5373	5437	55	5564	5627	[illegible]
685	83-	5691	5754	5817	5881	5944	6007	6071	6134	6197	6261	[illegible]
686	83-	6324	6387	6451	6514	6577	6641	6704	6767	683	6894	[illegible]
687	83-	6957	702	7083	7146	721	7273	7336	7399	7462	7525	[illegible]
688	83-	7588	7652	7715	7778	7841	7904	7967	803	8093	8156	[illegible]
689	83-	8219	8282	8345	8408	8471	8534	8597	866	8723	8786	[illegible]
690	83-	8849	8912	8975	9038	9101	9164	9227	9289	9352	9415	[illegible]
691	83-	9478	9541	9604	9667	9729	9792	9855	9918	9981	—	[illegible]
691	84-	—	—	—	—	—	—	—	—	—	0043	[illegible]
692	84	0106	0169	0232	0294	0357	042	0482	0545	0608	0671	[illegible]
693	84-	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	[illegible]
694	84-	1359	1422	1485	1547	161	1672	1735	1797	186	1922	[illegible]
695	84-	1985	2047	211	2172	2235	2297	236	2422	2484	2547	[illegible]
696	84-	2609	2672	2734	2796	2859	2921	2983	3046	3108	317	[illegible]
697	84-	3233	3295	3357	342	3482	3544	3606	3669	3731	3793	[illegible]
698	84-	3855	3918	398	4042	4104	4166	4229	4291	4353	4415	[illegible]
699	84-	4477	4539	4601	4664	4726	4788	485	4912	4974	5036	[illegible]
700	84-	5098	516	5222	5284	5346	5408	547	5532	5594	5656	[illegible]
701	84-	5718	578	5842	5904	5966	6028	609	6151	6213	6275	[illegible]
702	84-	6337	6399	6461	6523	6585	6646	6708	677	6832	6894	[illegible]
703	84-	6955	7017	7079	7141	7202	7264	7326	7388	7449	7511	[illegible]
704	84-	7573	7634	7696	7758	7819	7881	7943	8004	8066	8127	[illegible]
No.		0	1	2	3	4	5	6	7	8	9	

No.		0	1	2	3	4	5	6	7	8	9	D
605	78-	1755	1827	1899	1971	2042	2114	2186	2258	2329	2401	72
606	78-	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	72
607	78-	3189	326	3332	3403	3475	3546	3618	3689	3761	3832	71
608	78-	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	71
609	78-	4617	4689	476	4831	4902	4974	5045	5116	5187	5259	71
610	78-	533	5401	5472	5543	5615	5686	5757	5828	5899	597	71
611	78-	6041	6112	6183	6254	6325	6396	6467	6538	6609	668	71
612	78-	6751	6822	6893	6964	7035	7106	7177	7248	7319	739	71
613	78-	746	7531	7602	7673	7744	7815	7885	7956	8027	8098	71
614	78-	8168	8239	831	8381	8451	8522	8593	8663	8734	8804	71
615	78-	8875	8946	9016	9087	9157	9228	9299	9369	944	951	71
616	78-	9581	9651	9722	9792	9863	9933	—	—	—	—	70
616	79-	—	—	—	—	—	—	0004	0074	0144	0215	70
617	79-	0285	0356	0426	0496	0567	0637	0707	0778	0848	0918	70
618	79-	0988	1059	1129	1199	1269	134	141	148	155	162	70
619	79-	1691	1761	1831	1901	1971	2041	2111	2181	2252	2322	70
620	79-	2392	2462	2532	2602	2672	2742	2812	2882	2952	3022	70
621	79-	3092	3162	3231	3301	3371	3441	3511	3581	3651	3721	70
622	79-	379	386	393	4	407	4139	4209	4279	4349	4418	70
623	79-	4488	4558	4627	4697	4767	4836	4906	4976	5045	5115	70
624	79-	5185	5254	5324	5393	5463	5532	5602	5672	5741	5811	70
625	79-	588	5949	6019	6088	6158	6227	6297	6366	6436	6505	69
626	79-	6574	6644	6713	6782	6852	6921	699	706	7129	7198	69
627	79-	7268	7337	7406	7475	7545	7614	7683	7752	7821	789	69
628	79-	796	8029	8098	8167	8236	8305	8374	8443	8513	8582	69
629	79-	8651	872	8789	8858	8927	8996	9065	9134	9203	9272	69
630	79-	9341	9409	9478	9547	9616	9685	9754	9823	9892	9961	69
631	80-	0029	0098	0167	0236	0305	0373	0442	0511	058	0648	69
632	80-	0717	0786	0854	0923	0992	1061	1129	1198	1266	1335	69
633	80-	1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	69
634	80-	2089	2158	2226	2295	2363	2432	25	2568	2637	2705	69
635	80-	2774	2842	291	2979	3047	3116	3184	3252	3321	3389	68
636	80-	3457	3525	3594	3662	373	3798	3867	3935	4003	4071	68
637	80-	4139	4208	4276	4344	4412	448	4548	4616	4685	4753	68
638	80-	4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
639	80-	5501	5569	5637	5705	5773	5841	5908	5976	6044	6112	68
640	80-	618	6248	6316	6384	6451	6519	6587	6655	6723	679	68
641	80-	6858	6926	6994	7061	7129	7197	7264	7332	74	7467	68
642	80-	7535	7603	767	7738	7806	7873	7941	8008	8076	8143	68
643	80-	8211	8279	8346	8414	8481	8549	8616	8684	8751	8818	67
644	80-	8886	8953	9021	9088	9156	9223	929	9358	9425	9492	67
645	80-	956	9627	9694	9762	9829	9896	9964	—	—	—	67
645	81-	—	—	—	—	—	—	—	0031	0098	0165	67
646	81-	0233	03	0367	0434	0501	0569	0636	0703	077	0837	67
647	81-	0904	0971	1039	1106	1173	124	1307	1374	1441	1508	67
648	81-	1575	1642	1709	1776	1843	191	1977	2044	2111	2178	67
649	81-	2245	2312	2379	2445	2512	2579	2646	2713	278	2847	67
650	81-	2913	298	3047	3114	3181	324[illegible]		3381	3448	3514	67
651	81-	3581	3648	3714	3781	3848	39[illegible]					[illegible]
652	81-	4248	4314	4381	4447	4514	45[illegible]					
653	81-	4913	498	5046	5113	5179	52[illegible]					
654	81-	5578	5644	5711	5777	5843	59					
No.		0	1	2	3	4	5					

No.		0	1	2	3	4	5	6	7	8	9	D
655	81-	6241	6308	6374	644	6506	6573	6639	6705	6771	6838	66
656	81-	6904	697	7036	7102	7169	7235	7301	7367	7433	7499	66
657	81-	7565	7631	7698	7764	783	7896	7962	8028	8094	816	66
658	81-	8226	8292	8358	8424	849	8556	8622	8688	8754	882	66
659	81-	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
660	81-	9544	961	9676	9741	9807	9873	9939	—	—	—	66
660	82-	—	—	—	—	—	—	—	0004	007	0136	66
661	82-	0201	0267	0333	0399	0464	053	0595	0661	0727	0792	66
662	82-	0858	0924	0989	1055	112	1186	1251	1317	1382	1448	66
663	82-	1514	1579	1645	171	1775	1841	1906	1972	2037	2103	65
664	82-	2168	2233	2299	2364	243	2495	256	2626	2691	2756	65
665	82-	2822	2887	2952	3018	3083	3148	3213	3279	3344	3409	65
666	82-	3474	3539	3605	367	3735	38	3865	393	3996	4061	65
667	82-	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	65
668	82-	4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	65
669	82-	5426	5491	5556	5621	5686	5751	5815	588	5945	601	65
670	82-	6075	614	6204	6269	6334	6399	6464	6528	6593	6658	65
671	82-	6723	6787	6852	6917	6981	7046	7111	7175	724	7305	65
672	82-	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	65
673	82-	8015	808	8144	8209	8273	8338	8402	8467	8531	8595	64
674	82-	866	8724	8789	8853	8918	8982	9046	9111	9175	9239	64
675	82-	9304	9368	9432	9497	9561	9625	969	9754	9818	9882	64
676	82-	9947	—	—	—	—	—	—	—	—	—	64
676	83-	—	0011	0075	0139	0204	0268	0332	0396	046	0525	64
677	83-	0589	0653	0717	0781	0845	0909	0973	1037	1102	1166	64
678	83-	123	1294	1358	1422	1486	155	1614	1678	1742	1806	64
679	83-	187	1934	1998	2062	2126	2189	2253	2317	2381	2445	64
680	83-	2509	2573	2637	27	2764	2828	2892	2956	302	3083	64
681	83-	3147	3211	3275	3338	3402	3466	353	3593	3657	3721	64
682	83-	3784	3848	3912	3975	4039	4103	4166	423	4294	4357	64
683	83-	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	64
684	83-	5056	512	5183	5247	531	5373	5437	55	5564	5627	63
685	83-	5691	5754	5817	5881	5944	6007	6071	6134	6197	6261	63
686	83-	6324	6387	6451	6514	6577	6641	6704	6767	683	6894	63
687	83-	6957	702	7083	7146	721	7273	7336	7399	7462	7525	63
688	83-	7588	7652	7715	7778	7841	7904	7967	803	8093	8156	63
689	83-	8219	8282	8345	8408	8471	8534	8597	866	8723	8786	63
690	83-	8849	8912	8975	9038	9101	9164	9227	9289	9352	9415	63
691	83-	9478	9541	9604	9667	9729	9792	9855	9918	9981	—	63
691	84-	—	—	—	—	—	—	—	—	—	0043	63
692	84	0106	0169	0232	0294	0357	042	0482	0545	0608	0671	63
693	84-	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	63
694	84-	1359	1422	1485	1547	161	1672	1735	1797	186	1923	63
695	84-	1985	2047	211	2172	2235	2297	236	2422	2484	2547	62
696	84-	2609	2672	2734	2796	2859	2921	2983	3046	3108	317	62
697	84-	3233	3295	3357	342	3482	3544	3606	3669	3731	3793	62
698	84-	3855	3918	398	4042	4104	4166	4229	4291	4353	4415	62
600	84-	4477	4539	4601	4664	4726	4788	485	4912	4974	5036	62
	84-	5098	516	5222	5284	5346	5408	547	5532	5594	5656	62
	84-	5718	578	5842	5904	5966	6028	609	6151	6213	6275	62
		6337	6399	6461	6523	6585	6646	6708	677	6832	6894	62
		[illegible]	7017	7079	7141	7202	7264	7326	7388	7449	7511	[illegible]
				[illegible]	7758	7819	7881	7943	8004	8066	8127	
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9	8251	8312	8374	8435	8497	8559	862	8682	8743	62
5	8866	8928	8989	9051	9112	9174	9235	9297	9358	61
9	9481	9542	9604	9665	9726	9788	9849	9911	9972	61
3	0095	0156	0217	0279	034	0401	0462	0524	0585	61
6	0707	0769	083	0891	0952	1014	1075	1136	1197	61
8	132	1381	1442	1503	1564	1625	1686	1747	1809	61
7	1931	1992	2053	2114	2175	2236	2297	2358	2419	61
3	2541	2602	2663	2724	2785	2846	2907	2968	3029	61
)	315	3211	3272	3333	3394	3455	3516	3577	3637	61
8	3759	382	3881	3941	4002	4063	4124	4185	4245	61
6	4367	4428	4488	4549	461	467	4731	4792	4852	61
3	4974	5034	5095	5156	5216	5277	5337	5398	5459	61
19	558	564	5701	5761	5822	5882	5943	6003	6064	61
24	6185	6245	6306	6366	6427	6487	6548	6608	6668	60
29	6789	685	691	697	7031	7091	7152	7212	7272	60
32	7393	7453	7513	7574	7634	7694	7755	7815	7875	60
35	7995	8056	8116	8176	8236	8297	8357	8417	8477	60
37	8597	8657	8718	8778	8838	8898	8958	9018	9078	60
38	9198	9258	9318	9379	9439	9499	9559	9619	9679	60
39	9799	9859	9918	9978	—	—	—	—	—	60
-	—	—	—	—	0038	0098	0158	0218	0278	60
38	0398	0458	0518	0578	0637	0697	0757	0817	0877	60
37	0996	1056	1116	1176	1236	1295	1355	1415	1475	60
34	1594	1654	1714	1773	1833	1893	1952	2012	2072	60
31	2191	2251	231	237	243	2489	2549	2608	2668	60
28	2787	2847	2906	2966	3025	3085	3144	3204	3263	60
23	3382	3442	3501	3561	362	368	3739	3799	3858	59
17	3977	4036	4096	4155	4214	4274	4333	4392	4452	59
11	457	463	4689	4748	4808	4867	4926	4985	5045	59
04	5163	5222	5282	5341	54	5459	5519	5578	5637	59
96	5755	5814	5874	5933	5992	6051	611	6169	6228	59
87	6346	6405	6465	6524	6583	6642	6701	676	6819	59
78	6937	6996	7055	7114	7173	7232	7291	735	7409	59
67	7526	7585	7644	7703	7762	7821	788	7939	7998	59
56	8115	8174	8233	8292	835	8409	8468	8527	8586	59
44	8703	8762	8821	8879	8938	8997	9056	9114	9173	59
32	929	9349	9408	9466	9525	9584	9642	9701	976	59
18	9877	9935	9994	—	—	—	—	—	—	59
-	—	—	—	0053	0111	017	0228	0287	0345	59
04	0462	0521	0579	0638	0696	0755	0813	0872	093	58
89	1047	1106	1164	1223	1281	1339	1398	1456	1515	[illegible]
73	1631	169	1748	1806	1865	1923	1981	204	[illegible]	[illegible]
56	2215	2273	2331	2389	2448	2506	2564	[illegible]	[illegible]	[illegible]
39	2797	2855	2913	2972	303	3088	3146	[illegible]	[illegible]	[illegible]
11	3379	3437	3495	3553	3611	3669	[illegible]	[illegible]	[illegible]	[illegible]
02	396	4018	4076	4134	4192	425	[illegible]	[illegible]	[illegible]	[illegible]
82	454	4598	4656	4714	4772	483	[illegible]	[illegible]	[illegible]	[illegible]
61	5119	5177	5235	5293	5351	5409	[illegible]	[illegible]	[illegible]	[illegible]
.	5698	5756	5813	5871	5929	5987	6045	[illegible]	[illegible]	[illegible]
8	6276	6333	6391	6449	6507	6564	[illegible]	[illegible]	[illegible]	[illegible]
5	6853	691	6968	7026	7083	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	7429	7487	7544	7602	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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855	93- 1966	2017	2068	2118	2169	222	2271	2322	2372	2423	51
856	93- 2474	2524	2575	2626	2677	2727	2778	2829	2879	293	51
857	93- 2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	51
858	93- 3487	3538	3589	3639	369	374	3791	3841	3892	3943	51
859	93- 3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	51
860	93- 4498	4549	4599	465	47	4751	4801	4852	4902	4953	50
861	93- 5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	50
862	93- 5507	5558	5608	5658	5709	5759	5809	586	591	596	50
863	93- 6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	50
864	93- 6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	50
865	93- 7016	7066	7117	7167	7217	7267	7317	7367	7418	7468	50
866	93- 7518	7568	7618	7668	7718	7769	7819	7869	7919	7969	50
867	93- 8019	8069	8119	8169	8219	8269	8319	837	842	847	50
868	93- 852	857	862	867	872	877	882	887	892	897	50
869	93- 902	907	912	917	922	927	932	9369	9419	9469	50
870	93- 9519	9569	9619	9669	9719	9769	9819	9869	9918	9968	50
871	94- 0018	0068	0118	0168	0218	0267	0317	0367	0417	0467	50
872	94- 0516	0566	0616	0666	0716	0765	0815	0865	0915	0964	50
873	94- 1014	1064	1114	1163	1213	1263	1313	1362	1412	1462	50
874	94- 1511	1561	1611	166	171	176	1809	1859	1909	1958	50
875	94- 2008	2058	2107	2157	2207	2256	2306	2355	2405	2455	50
876	94- 2504	2554	2603	2653	2702	2752	2801	2851	2901	295	50
877	94- 3	3049	3099	3148	3198	3247	3297	3346	3396	3445	[illegible]
878	94- 3495	3544	3593	3643	3692	3742	3791	3841	389	3939	[illegible]
879	94- 3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	[illegible]
880	94- 4483	4532	4581	4631	468	4729	4779	4828	4877	4927	[illegible]
881	94- 4976	5025	5074	5124	5173	5222	5272	5321	537	5419	[illegible]
882	94- 5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	[illegible]
883	94- 5961	601	6059	6108	6157	6207	6256	6305	6354	6403	[illegible]
884	94- 6452	6501	6551	66	6649	6698	6747	6796	6845	6894	[illegible]
885	94- 6943	6992	7041	709	714	7189	7238	7287	7336	7385	[illegible]
886	94- 7434	7483	7532	7581	763	7679	7728	7777	7826	7875	[illegible]
887	94- 7924	7973	8022	807	8119	8168	8217	8266	8315	8364	[illegible]
888	94- 8413	8462	8511	856	8609	8657	8706	8755	8804	8853	[illegible]
889	94- 8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	[illegible]
890	94- 939	9439	9488	9536	9585	9634	9683	9731	978	9829	[illegible]
891	94- 9878	9926	9975	—	—	—	—	—	—	—	[illegible]
891	95- —	—	—	0024	0073	0121	017	0219	0267	0316	[illegible]
892	95- 0365	0414	0462	0511	056	0608	0657	0706	0754	0803	[illegible]
893	95- 0851	09	0949	0997	1046	1095	1143	1192	124	1289	[illegible]
894	95- 1338	1386	1435	1483	1532	158	1629	1677	1726	1775	[illegible]
895	95- 1823	1872	192	1969	2017	2066	2114	2163	2211	226	[illegible]
896	95- 2308	2356	2405	2453	2502	255	2599	2647	2696	2744	[illegible]
897	95- 2792	2841	2889	2938	2986	3034	3083	3131	318	3228	[illegible]
898	95- 3276	3325	3373	3421	347	3518	3566	3615	3663	3711	[illegible]
899	95- 376	3808	3856	3905	3953	4001	4049	4098	4146	4194	[illegible]
900	95- 4243	4291	4339	4387	4435	4484	4532	458	4628	4677	[illegible]
901	95- 4725	4773	4821	4869	4918	4966	5014	5062	511	5158	[illegible]
902	95- 5207	5255	5303	5351	5399	5447	5495	5543	5592	564	[illegible]
903	95- 5688	5736	5784	5832	588	5928	5976	6024	6072	612	[illegible]
904	95- 6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	[illegible]
No.	0	1	2	3	4	5	6	7	8	9	

N.		0	1	2	3	4	5	6	7	8	9	D
5	90-	5796	585	5904	5958	6012	6066	6119	6173	6227	6281	54
6	90-	6335	6389	6443	6497	6551	6604	6658	6712	6766	682	54
7	90-	6874	6927	6981	7035	7089	7143	7196	725	7304	7358	54
8	90-	7411	7465	7519	7573	7626	768	7734	7787	7841	7895	54
9	90-	7949	8002	8056	811	8163	8217	827	8324	8378	8431	54
0	90-	8485	8539	8592	8646	8699	8753	8807	886	8914	8967	54
1	90-	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	54
2	90-	9556	9609	9663	9716	977	9823	9877	993	9984	—	54
2	91-	—	—	—	—	—	—	—	—	—	0037	53
3	91-	0091	0144	0197	0251	0304	0358	0411	0464	0518	0571	53
4	91-	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	53
5	91-	1158	1211	1264	1317	1371	1424	1477	153	1584	1637	53
6	91-	169	1743	1797	185	1903	1956	2009	2063	2116	2169	53
7	91-	2222	2275	2328	2381	2435	2488	2541	2594	2647	27	53
8	91-	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	53
9	91-	3284	3337	339	3443	3496	3549	3602	3655	3708	3761	53
0	91-	3814	3867	392	3973	4026	4079	4132	4184	4237	429	53
1	91-	4343	4396	4449	4502	4555	4608	466	4713	4766	4819	53
2	91-	4872	4925	4977	503	5083	5136	5189	5241	5294	5347	53
3	91-	54	5453	5505	5558	5611	5664	5716	5769	5822	5875	53
4	91-	5927	598	6033	6085	6138	6191	6243	6296	6349	6401	53
5	91-	6454	6507	6559	6612	6664	6717	677	6822	6875	6927	53
6	91-	698	7033	7085	7138	719	7243	7295	7348	74	7453	53
7	91-	7506	7558	7611	7663	7716	7768	782	7873	7925	7978	52
8	91-	803	8083	8135	8188	824	8293	8345	8397	845	8502	52
9	91-	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	52
0	91-	9078	913	9183	9235	9287	934	9392	9444	9496	9549	52
1	91-	9601	9653	9706	9758	981	9862	9914	9967	—	—	52
1	92-	—	—	—	—	—	—	—	—	0019	0071	52
2	92-	0123	0176	0228	028	0332	0384	0436	0489	0541	0593	52
3	92-	0645	0697	0749	0801	0853	0906	0958	101	1062	1114	52
4	92-	1166	1218	127	1322	1374	1426	1478	153	1582	1634	52
5	92-	1686	1738	179	1842	1894	1946	1998	205	2102	2154	52
6	92-	2206	2258	231	2362	2414	2466	2518	257	2622	2674	52
7	92-	2725	2777	2829	2881	2933	2985	3037	3089	314	3192	52
8	92-	3244	3296	3348	3399	3451	3503	3555	3607	3658	371	52
9	92-	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	52
0	92-	4279	4331	4383	4434	4486	4538	4589	4641	4693	4744	52
	92-	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	52
	92-	5312	5364	5415	5467	5518	557	5621	5673	5725	5776	52
	92-	5828	5879	5931	5982	6034	6085	6137	6188	624	6291	51
	92-	6342	6394	6445	6497	6548	66	6651	6702	6754	6805	51
	92-	6857	6908	6959	7011	7062	7114	7165	7216	7268	7319	51
	92-	737	7422	7473	7524	7576	7627	7678	773	7781	7832	51
	92-	7883	7935	7986	8037	8088	814	8191	8242	8293	8345	51
	92-	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	51
	92-	8908	8959	901	9061	9112	9163	9215	9266	9317	9368	51
	92-	9419	947	9521	9572	9623	9674	9725	9776	9827	9879	51
	92-	993	9981	—	—	—	—	—	—	—	—	51
	93-	—	—	0032	0083	0134	0185	0236	0287	0338	0389	51
	93-	044	0491	0542	0592	0643	0694	0745	0796	0847	0898	51
	93-	0949	1	1051	1102	1153	1203	1254	1305	1356	1407	51
	93-	1458	1509	156	161	1661	1712	1763	1814	1865	1915	51
		0	1	2	3	4	5	6	7			

No.	0	1	2	3	4	5	6	7	8	9	D
955	98- 0003	0049	0094	014	0185	0231	0276	0322	0367	0412	45
956	98- 0458	0503	0549	0594	064	0685	073	0776	0821	0867	45
957	98- 0912	0957	1003	1048	1093	1139	1184	1229	1275	132	45
958	98- 1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	45
959	98- 1819	1864	1909	1954	2	2045	209	2135	2181	2226	45
960	98- 2271	2316	2362	2407	2452	2497	2543	2588	2633	2678	45
961	98- 2723	2769	2814	2859	2904	2949	2994	304	3085	313	45
962	98- 3175	322	3265	331	3356	3401	3446	3491	3536	3581	45
963	98- 3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	45
964	98- 4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	45
965	98- 4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
966	98- 4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	45
967	98- 5426	5471	5516	5561	5606	5651	5696	5741	5786	583	45
968	98- 5875	592	5965	601	6055	61	6144	6189	6234	6279	45
969	98- 6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	45
970	98- 6772	6817	6861	6906	6951	6996	704	7085	713	7175	45
971	98- 7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	45
972	98- 7666	7711	7756	78	7845	789	7934	7979	8024	8068	45
973	98- 8113	8157	8202	8247	8291	8336	8381	8425	847	8514	45
974	98- 8559	8604	8648	8693	8737	8782	8826	8871	8916	896	45
975	98- 9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	45
976	98- 945	9494	9539	9583	9628	9672	9717	9761	9806	985	44
977	98- 9895	9939	9983	—	—	—	—	—	—	—	44
977	99- —	—	—	0028	0072	0117	0161	0206	025	0294	44
978	99- 0339	0383	0428	0472	0516	0561	0605	065	0694	0738	44
979	99- 0783	0827	0871	0916	096	1004	1049	1093	1137	1182	44
980	99- 1226	127	1315	1359	1403	1448	1492	1536	158	1625	44
981	99- 1669	1713	1758	1802	1846	189	1935	1979	2023	2067	44
982	99- 2111	2156	22	2244	2288	2333	2377	2421	2465	2509	44
983	99- 2554	2598	2642	2686	273	2774	2819	2863	2907	2951	44
984	99- 2995	3039	3083	3127	3172	3216	326	3304	3348	3392	44
985	99- 3436	348	3524	3568	3613	3657	3701	3745	3789	3833	44
986	99- 3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	44
987	99- 4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
988	99- 4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	44
989	99- 5196	524	5284	5328	5372	5416	546	5504	5547	5591	44
990	99- 5635	5679	5723	5767	5811	5854	5898	5942	5986	603	44
991	99- 6074	6117	6161	6205	6249	6293	6337	638	6424	6468	44
992	99- 6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	44
993	99- 6949	6993	7037	708	7124	7168	7212	7255	7299	7343	44
994	99- 7386	743	7474	7517	7561	7605	7648	7692	7736	7779	44
995	99- 7823	7867	791	7954	7998	8041	8085	8129	8172	8216	44
996	99- 8259	8303	8347	839	8434	8477	8521	8564	8608	8652	44
997	99- 8695	8739	8782	8826	8869	8913	8956	9	9043	9087	44
998	99- 9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	44
999	99- 9565	9609	9652	9696	9739	9783	9826	987	9913	9957	44
	0	1	2	3	4	5	6	7	8	9	

Hyperbolic Logarithms of Numbers.

From 1.01 *to* 30.

following table, the numbers range from 1.01 to 30, advancing by .01, the whole number 10; and thence by larger intervals up to 30. The rbolic logarithms of numbers, or Neperian logarithms, as they are somes termed, are computed by multiplying the common logarithms of numby the constant multiplier, 2.302 585.

1e hyperbolic logarithms of numbers intermediate between those which given in the table may be readily obtained by interpolating proportional rences.

	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
	.0099	1.41	.3436	1.81	.5933	2.21	.793	2.61	.9594
	.0198	1.42	.3507	1.82	.5988	2.22	.7975	2.62	.9632
	.0296	1.43	.3577	1.83	.6043	2.23	.802	2.63	.967
	.0392	1.44	.3646	1.84	.6098	2.24	.8065	2.64	.9708
	.0488	1.45	.3716	1.85	.6152	2.25	.8109	2.65	.9746
	.0583	1.46	.3784	1.86	.6206	2.26	.8154	2.66	.9783
	.0677	1.47	.3853	1.87	.6259	2.27	.8198	2.67	.9821
	.077	1.48	.392	1.88	.6313	2.28	.8242	2.68	.9858
	.0862	1.49	.3988	1.89	.6366	2.29	.8286	2.69	.9895
	.0953	1.5	.4055	1.9	.6419	2.3	.8329	2.7	.9933
1	.1044	1.51	.4121	1.91	.6471	2.31	.8372	2.71	.9969
2	.1133	1.52	.4187	1.92	.6523	2.32	.8416	2.72	1.0006
3	.1222	1.53	.4253	1.93	.6575	2.33	.8458	2.73	1.0043
4	.131	1.54	.4318	1.94	.6627	2.34	.8502	2.74	1.008
5	.1398	1.55	.4383	1.95	.6678	2.35	.8544	2.75	1.0116
6	.1484	1.56	.4447	1.96	.6729	2.36	.8587	2.76	1.0152
7	.157	1.57	.4511	1.97	.678	2.37	.8629	2.77	1.0188
8	.1655	1.58	.4574	1.98	.6831	2.38	.8671	2.78	1.0225
9	.174	1.59	.4637	1.99	.6881	2.39	.8713	2.79	1.026
	.1823	1.6	.47	2	.6931	2.4	.8755	2.8	1.0296
1	.1906	1.61	.4762	2.01	.6981	2.41	.8796	2.81	1.0332
2	.1988	1.62	.4824	2.02	.7031	2.42	.8838	2.82	1.0367
3	.207	1.63	.4886	2.03	.708	2.43	.8879	2.83	1.0403
4	.2151	1.64	.4947	2.04	.7129	2.44	.892	2.84	1.0438
5	.2231	1.65	.5008	2.05	.7178	2.45	.8961	2.85	1.0473
6	.2311	1.66	.5068	2.06	.7227	2.46	.9002	2.86	1.0508
7	.239	1.67	.5128	2.07	.7275	2.47	.9042	2.87	1.0543
8	.2469	1.68	.5188	2.08	.7324	2.48	.9083	2.88	1.0578
9	.2546	1.69	.5247	2.09	.7372	2.49	.9123	2.89	1.0613
	.2624	1.7	.5306	2.1	.7419	2.5	.9163	2.9	1.0647
1	.27	1.71	.5365	2.11	.7467	2.51	.9203	2.91	1.0
2	.2776	1.72	.5423	2.12	.7514	2.52	.9243	2.92	1.
3	.2852	1.73	.5481	2.13	.7561	2.53	.9282	2.93	1.
4	.2927	1.74	.5539	2.14	.7608	2.54	.9322	2.94	1.
5	.3001	1.75	.5596	2.15	.7655	2.55	.9361	2.95	1.
6	.3075	1.76	.5653	2.16	.7701	2.56		5	1.0
7	.3148	1.77	.571	2.17	.7747	2.57			1.0
8	.3221	1.78	.5766	2.18	.7793	2.58			
9	.3293	1.79	.5822	2.19	.7839	2.59			
	.3365	1.8	.5878	2.2	.7885	2.6			

	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
:	1.7066	6.01	1.7934	6.51	1.8733	7.01	1.9473	7.51	2.0162
2	1.7084	6.02	1.7951	6.52	1.8749	7.02	1.9488	7.52	2.0176
3	1.7102	6.03	1.7967	6.53	1.8764	7.03	1.9502	7.53	2.0189
4	1.712	6.04	1.7984	6.54	1.8779	7.04	1.9516	7.54	2.0202
5	1.7138	6.05	1.8001	6.55	1.8795	7.05	1.953	7.55	2.0215
5	1.7156	6.06	1.8017	6.56	1.881	7.06	1.9544	7.56	2.0229
7	1.7174	6.07	1.8034	6.57	1.8825	7.07	1.9559	7.57	2.0242
8	1.7192	6.08	1.805	6.58	1.884	7.08	1.9573	7.58	2.0255
9	1.721	6.09	1.8066	6.59	1.8856	7.09	1.9587	7.59	2.0268
	1.7228	6.1	1.8083	6.6	1.8871	7.1	1.9601	7.6	2.0281
1	1.7246	6.11	1.8099	6.61	1.8886	7.11	1.9615	7.61	2.0295
2	1.7263	6.12	1.8116	6.62	1.8901	7.12	1.9629	7.62	2.0308
3	1.7281	6.13	1.8132	6.63	1.8916	7.13	1.9643	7.63	2.0321
4	1.7299	6.14	1.8148	6.64	1.8931	7.14	1.9657	7.64	2.0334
5	1.7317	6.15	1.8165	6.65	1.8946	7.15	1.9671	7.65	2.0347
6	1.7334	6.16	1.8181	6.66	1.8961	7.16	1.9685	7.66	2.036
7	1.7352	6.17	1.8197	6.67	1.8976	7.17	1.9699	7.67	2.0373
8	1.737	6.18	1.8213	6.68	1.8991	7.18	1.9713	7.68	2.0386
9	1.7387	6.19	1.8229	6.69	1.9006	7.19	1.9727	7.69	2.0399
	1.7405	6.2	1.8245	6.7	1.9021	7.2	1.9741	7.7	2.0412
1	1.7422	6.21	1.8262	6.71	1.9036	7.21	1.9755	7.71	2.0425
2	1.744	6.22	1.8278	6.72	1.9051	7.22	1.9769	7.72	2.0438
3	1.7457	6.23	1.8294	6.73	1.9066	7.23	1.9782	7.73	2.0451
4	1.7475	6.24	1.831	6.74	1.9081	7.24	1.9796	7.74	2.0464
5	1.7492	6.25	1.8326	6.75	1.9095	7.25	1.981	7.75	2.0477
5	1.7509	6.26	1.8342	6.76	1.911	7.26	1.9824	7.76	2.049
7	1.7527	6.27	1.8358	6.77	1.9125	7.27	1.9838	7.77	2.0503
8	1.7544	6.28	1.8374	6.78	1.914	7.28	1.9851	7.78	2.0516
9	1.7561	6.29	1.839	6.79	1.9155	7.29	1.9865	7.79	2.0528
	1.7579	6.3	1.8405	6.8	1.9169	7.3	1.9879	7.8	2.0541
1	1.7596	6.31	1.8421	6.81	1.9184	7.31	1.9892	7.81	2.0554
2	1.7613	6.32	1.8437	6.82	1.9199	7.32	1.9906	7.82	2.0567
3	1.763	6.33	1.8453	6.83	1.9213	7.33	1.992	7.83	2.058
4	1.7647	6.34	1.8469	6.84	1.9228	7.34	1.9933	7.84	2.0592
5	1.7664	6.35	1.8485	6.85	1.9242	7.35	1.9947	7.85	2.0605
5	1.7681	6.36	1.85	6.86	1.9257	7.36	1.9961	7.86	2.0618
7	1.7699	6.37	1.8516	6.87	1.9272	7.37	1.9974	7.87	2.0631
8	1.7716	6.38	1.8532	6.88	1.9286	7.38	1.9988	7.88	2.0643
9	1.7733	6.39	1.8547	6.89	1.9301	7.39	2.0001	7.89	2.0656
	1.775	6.4	1.8563	6.9	1.9315	7.4	2.0015	7.9	2.0669
	1.7766	6.41	1.8579	6.91	1.933	7.41	2.0028	7.91	2.068-
	1.7783	6.42	1.8594	6.92	1.9344	7.42	2.0042	7.92	2.0
	1.78	6.43	1.861	6.93	1.9359	7.43	2.0055	7.93	2.0
	1.7817	6.44	1.8625	6.94	1.9373			7.94	2.0
	1.7834	6.45	1.8641	6.95	1.9387			7.95	2.0
	1.7851	6.46	1.8656	6.96	1.9402			6	2.0
	1.7867	6.47	1.8672	6.97	1.9416				2.0
	1.7884	6.48	1.8687	6.98	1.943				
	1.7901	6.49	1.8703	6.99	1.9445				
	1.7918	6.5	1.8718	7	1.9459				

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
8.01	2.0807	8.41	2.1294	8.81	2.1759	9.21	2.2203	9.61	2.[illegible]
8.02	2.0819	8.42	2.1306	8.82	2.177	9.22	2.2214	9.62	2.[illegible]
8.03	2.0832	8.43	2.1318	8.83	2.1782	9.23	2.2225	9.63	2.[illegible]
8.04	2.0844	8.44	2.133	8.84	2.1793	9.24	2.2235	9.64	2.[illegible]
8.05	2.0857	8.45	2.1342	8.85	2.1804	9.25	2.2246	9.65	2.[illegible]
8.06	2.0869	8.46	2.1353	8.86	2.1815	9.26	2.2257	9.66	2.[illegible]
8.07	2.0882	8.47	2.1365	8.87	2.1827	9.27	2.2268	9.67	2.[illegible]
8.08	2.0894	8.48	2.1377	8.88	2.1838	9.28	2.2279	9.68	2.[illegible]
8.09	2.0906	8.49	2.1389	8.89	2.1849	9.29	2.2289	9.69	2.[illegible]
8.1	2.0919	8.5	2.1401	8.9	2.1861	9.3	2.23	9.7	2.[illegible]
8.11	2.0931	8.51	2.1412	8.91	2.1872	9.31	2.2311	9.71	2.[illegible]
8.12	2.0943	8.52	2.1424	8.92	2.1883	9.32	2.2322	9.72	2.[illegible]
8.13	2.0956	8.53	2.1436	8.93	2.1894	9.33	2.2332	9.73	2.[illegible]
8.14	2.0968	8.54	2.1448	8.94	2.1905	9.34	2.2343	9.74	2.[illegible]
8.15	2.098	8.55	2.1459	8.95	2.1917	9.35	2.2354	9.75	2.[illegible]
8.16	2.0992	8.56	2.1471	8.96	2.1928	9.36	2.2364	9.76	2.[illegible]
8.17	2.1005	8.57	2.1483	8.97	2.1939	9.37	2.2375	9.77	2[illegible]
8.18	2.1017	8.58	2.1494	8.98	2.195	9.38	2.2386	9.78	2[illegible]
8.19	2.1029	8.59	2.1506	8.99	2.1961	9.39	2.2396	9.79	2.[illegible]
8.2	2.1041	8.6	2.1518	9	2.1972	9.4	2.2407	9.8	2.[illegible]
8.21	2.1054	8.61	2.1529	9.01	2.1983	9.41	2.2418	9.81	2.[illegible]
8.22	2.1066	8.62	2.1541	9.02	2.1994	9.42	2.2428	9.82	2.[illegible]
8.23	2.1078	8.63	2.1552	9.03	2.2006	9.43	2.2439	9.83	2[illegible]
8.24	2.109	8.64	2.1564	9.04	2.2017	9.44	2.245	9.84	2.[illegible]
8.25	2.1102	8.65	2.1576	9.05	2.2028	9.45	2.246	9.85	2.[illegible]
8.26	2.1114	8.66	2.1587	9.06	2.2039	9.46	2.2471	9.86	2.[illegible]
8.27	2.1126	8.67	2.1599	9.07	2.205	9.47	2.2481	9.87	2.[illegible]
8.28	2.1138	8.68	2.161	9.08	2.2061	9.48	2.2492	9.88	2.[illegible]
8.29	2.115	8.69	2.1622	9.09	2.2072	9.49	2.2502	9.89	2.[illegible]
8.3	2.1163	8.7	2.1633	9.1	2.2083	9.5	2.2513	9.9	2.[illegible]
8.31	2.1175	8.71	2.1645	9.11	2.2094	9.51	2.2523	9.91	2.[illegible]
8.32	2.1187	8.72	2.1656	9.12	2.2105	9.52	2.2534	9.92	2.[illegible]
[illegible]	[illegible]	8.73	2.1668	9.13	2.2116	9.53	2.2544	9.93	2.[illegible]
[illegible]	[illegible]	8.74	2.1679	9.14	2.2127	9.54	2.2555	9.94	2.[illegible]
[illegible]	[illegible]	8.75	2.1691	9.15	2.2138	9.55	2.2565	9.95	2.[illegible]
[illegible]	[illegible]	8.76	2.1702	9.16	2.2148	9.56	2.2576	9.96	2.[illegible]
[illegible]	[illegible]	8.77	2.1713	9.17	2.2159	9.57	2.2586	9.97	2.[illegible]
[illegible]	[illegible]	8.78	2.1725	9.18	2.217	9.58	2.2597	9.98	2.[illegible]
[illegible]	[illegible]	8.79	2.1736	9.19	2.2181	9.59	2.2607	9.99	2.[illegible]
[illegible]	[illegible]	8.8	2.1748	9.2	2.2192	9.6	2.2618	10	2.[illegible]
[illegible]	[illegible]	12.25	2.5052	14.25	2.6567	17.5	2.8621	23	3.[illegible]
[illegible]	[illegible]	12.5	2.5262	14.5	2.674	18	2.8904	24	3.[illegible]
[illegible]	[illegible]	12.75	[illegible]	14.75	2.6913	18.5	2.9173	25	3.[illegible]
[illegible]	[illegible]	13	[illegible]	[illegible]	2.7081	19	2.9444	26	3.[illegible]
[illegible]	[illegible]	13.25	[illegible]	[illegible]	2.7408	19.5	2.9703	27	3.[illegible]
[illegible]	[illegible]	13.5	[illegible]	[illegible]	2.7726	20	2.9957	28	3.[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.8034	21	3.0445	29	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.8332	22	3.0911	30	[illegible]

MENSURATION OF AREAS, LINES, AND SURFACES.

Parallelograms.

Definition.—Quadrilaterals, having their opposite sides parallel.

'o Compute Area of a Square, Rectangle, Rhombus, or Rhomboid.—Figs. 1, 2, 3, and 4.

Rule.—Multiply length by breadth or height.

Or, $l \times b =$ *area, l representing length, and b breadth.*

Fig. 1.

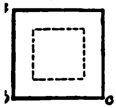


Fig. 2.

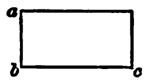


Fig. 3.

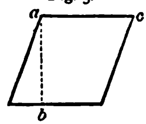
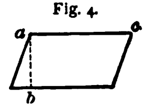


Fig. 4.



Example.—Sides $a\,b$, $b\,c$, Fig. 1, are 5 feet 6 ins.; what is area?

$5.5 \times 5.5 = 30.25$ *square feet.*

Note 1.—Opposite angles of a Rhombus and a Rhomboid are equal.

2.—In any parallelogram the four angles equal 360°.

3.—Side of a square multiplied by 1.52 is equal to side of an equilateral triangle 'equal area.

Gnomon.

Definition.—Space included between the lines forming two similar parallel- ;rams, of which smaller is inscribed within larger, so that one angle in each is ımmon to both, as shown by dotted lines, Fig. 1.

To Compute Area of a Gnomon.—Fig. 1.

Rule.—Ascertain areas of the two parallelograms, and subtract less from reater.

Or, $a - a' =$ *area, a and a' representing areas.*

Example.—Sides of a gnomon are 10 by 10 and 6 by 6 ins.; what is its area?

$10 \times 10 = 100$, and $6 \times 6 = 36$. Then $100 - 36 = 64$ *square ins.*

Triangles.

Definition.—Plain superficies having three sides and angles.

To Compute Area of a Triangle.—Figs. 5, 6, and 7.

Rule.—Multiply base by height, and divide product by 2.

Or, $\frac{ab \times cd}{2}$. Or, $\frac{b\,h}{2} =$ *area, b representing base, and h height.*

Note 1.—*Hypotenuse* of a right angle is side opposite to right angle.

2.—Perpendicular height of a triangle = twice its area divided by its base.

3.—Perpendicular height of an equilateral triangle = a side $\times$ .866.

4.—Side of an equilateral triangle $\times$ .658 2[illegible] = side of a square of equal area, Or $\div$ 1.3468 = diameter of a circle of e[illegible]al area.

Fig. 5.

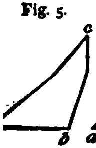
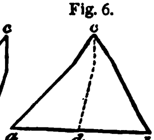
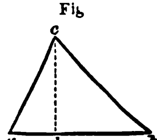


Fig. 6.



Fi[illegible]



No.	Log.	No.	Log.	No.	Log.	No.	Log.
8.01	2.0807	8.41	2.1294	8.81	2.1759	9.21	2.2203
8.02	2.0819	8.42	2.1306	8.82	2.177	9.22	2.2214
8.03	2.0832	8.43	2.1318	8.83	2.1782	9.23	2.2225
8.04	2.0844	8.44	2.133	8.84	2.1793	9.24	2.2235
8.05	2.0857	8.45	2.1342	8.85	2.1804	9.25	2.2246
8.06	2.0869	8.46	2.1353	8.86	2.1815	9.26	2.2257
8.07	2.0882	8.47	2.1365	8.87	2.1827	9.27	2.2268
8.08	2.0894	8.48	2.1377	8.88	2.1838	9.28	2.2279
8.09	2.0906	8.49	2.1389	8.89	2.1849	9.29	2.2289
8.1	2.0919	8.5	2.1401	8.9	2.1861	9.3	2.23
8.11	2.0931	8.51	2.1412	8.91	2.1872	9.31	2.2311
8.12	2.0943	8.52	2.1424	8.92	2.1883	9.32	2.2322
8.13	2.0956	8.53	2.1436	8.93	2.1894	9.33	2.2332
8.14	2.0968	8.54	2.1448	8.94	2.1905	9.34	2.2343
8.15	2.098	8.55	2.1459	8.95	2.1917	9.35	2.2354
8.16	2.0992	8.56	2.1471	8.96	2.1928	9.36	2.2364
8.17	2.1005	8.57	2.1483	8.97	2.1939	9.37	2.2375
8.18	2.1017	8.58	2.1494	8.98	2.195	9.38	2.2386
8.19	2.1029	8.59	2.1506	8.99	2.1961	9.39	2.2396
8.2	2.1041	8.6	2.1518	9	2.1972	9.4	2.2407
8.21	2.1054	8.61	2.1529	9.01	2.1983	9.41	2.2418
8.22	2.1066	8.62	2.1541	9.02	2.1994	9.42	2.2428
8.23	2.1078	8.63	2.1552	9.03	2.2006	9.43	2.2439
8.24	2.109	8.64	2.1564	9.04	2.2017	9.44	2.245
8.25	2.1102	8.65	2.1576	9.05	2.2028	9.45	2.246
8.26	2.1114	8.66	2.1587	9.06	2.2039	9.46	2.2471
8.27	2.1126	8.67	2.1599	9.07	2.205	9.47	2.2481
8.28	2.1138	8.68	2.161	9.08	2.2061	9.48	2.2492
8.29	2.115	8.69	2.1622	9.09	2.2072	9.49	2.2502
8.3	2.1163	8.7	2.1633	9.1	2.2083	9.5	2.2513
8.31	2.1175	8.71	2.1645	9.11	2.2094	9.51	2.2523
8.32	2.1187	8.72	2.1656	9.12	2.2105	9.52	2.2534
8.33	2.1199	8.73	2.1668	9.13	2.2116	9.53	2.2544
8.34	2.1211	8.74	2.1679	9.14	2.2127	9.54	2.2555
8.35	2.1223	8.75	2.1691	9.15	2.2138	9.55	2.2565
8.36	2.1235	8.76	2.1702	9.16	2.2148	9.56	2.2576
8.37	2.1247	8.77	2.1713	9.17	2.2159	9.57	2.2586
8.38	2.1258	8.78	2.1725	9.18	2.217	[illegible]	2.2597
8.39	2.127	8.79	[illegible]	9.19	[illegible]	[illegible]	2.2607
8.4	[illegible]	8.8	2.1748	9.2	[illegible]	[illegible]	2.2618
10.25	2.3279	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10.5	2.3513	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

F OF AREAS, LINES AND SURFACES.

Parallelograms.

...als, having their opposite sides parallel

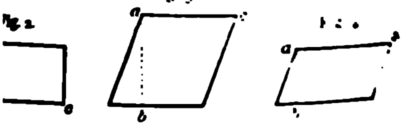
...of a Square, Rectangle, Rhombus, or ...boid.—Figs. 1, 2, 3, and 4.

...th by breadth or height.

...area, l representing length, and b breadth

Fig 3

Fig 2



..., Fig 1, are 5 feet 6 ins ...

5.5 × 5.5 = 30.25 *square feet*

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Triangles.

...es having three sides and angles

...of a Triangle.—Figs. 5, 6, and 7.

...ight, and divide product by 2

... b representing base ...

... side opposite ... is base

...wice its area ...

...angle ... a side ... of equal area,

... side of a square ...

...TRIANGLE.—Base a b, Fig. ... feet, and height c b, 6; what is area?

... = 12

... square feet

...se are given.

...e third of it ...ultiplied by

...alf arc, a b, is

...ird of it more.

...04 26 = 116.427

RULE.—Ascer-

...of a Circle.

...meter of circle, ...a Circle, p. 267, ...t.

...ght, take square

× 2 = c.

13.)

...e from centre.

...re.—Fig. 23.

...ference, and prod-

= surface.

...sphere, Fig. 23, hav-

...re ins.

...phere.—Fig. 24.

...nere, and add product

a b c, Fig. 24, is 36 ins., ..., is convex surface, and

... of segment multiplied by

...r and versed sine being ...ng equal to chord of arc,

... − 28² = 96.

... + 11 309.76 = 18 548.0064

...ired, area or areas of base

... circumference of a circle to

To Compute Area of a Triangle by Length of its Sides.—Figs. 6 and 7.

RULE.—From half sum of the three sides subtract each side separately; then multiply half sum and the three remainders continually together, and take square root of product.

Or, $\sqrt{(s-a) \times (s-b) \times (s-c)\, S} =$ *area, a, b, c representing sides, and* S *half sum of the three sides.*

EXAMPLE.—Sides of a triangle, Figs. 6 and 7, are 30, 40, and 50 feet; what is area?

$\frac{30+40+50}{2} = \frac{120}{2} = 60$, or half sum of sides. $\left.\begin{array}{l}60-30=30\\60-40=20\\60-50=10\end{array}\right\}$ *remainders.*

Whence, $30 \times 20 \times 10 \times 60 = 360\,000$, and $\sqrt{360\,000} = 600$ *square feet.*

When all Sides are Equal. RULE.—Square length of a side, and multiply product by .433.

Or, $S^2 \times .433 =$ *area,* S *representing length of a side.*

To Compute Length of One Side of a Right-Angled Triangle.

When Length of the other Two Sides are given.

To Ascertain Hypotenuse.—Fig. 5.

RULE.—Add together squares of the two legs, and take square root of sum.

Or, $\sqrt{a\,b^2 + b\,c^2} =$ *hypotenuse.* Or, $\sqrt{b^2 + h^2}$.

EXAMPLE.—Base, *a b*, Fig. 5, is 30 ins., and height, *b c*, 40; what is length of hypotenuse?

$30^2 + 40^2 = 2500$, and $\sqrt{2500} = 50$ *ins.*

To Ascertain other Leg.

When Hypotenuse and One of the Legs are given.—Fig. 5. RULE.—Subtract square of given leg from square of hypotenuse, and take square root of remainder.

Or, $\sqrt{hyp.^2 - \left\{\begin{array}{l}b^2 = h.\\h^2 = b.\end{array}\right.}$ Or, $\sqrt{a\,c^2 - \left\{\begin{array}{l}a\,b^2 = b\,c.\\b\,c^2 = a\,b.\end{array}\right.}$

EXAMPLE.—Base of a triangle, *a b*, Fig. 5, is 30 feet, and hypotenuse, *a c*, 50; what is height of it?

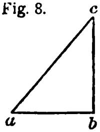
$50^2 - 30^2 = 1600$, and $\sqrt{1600} = 40$ *feet.*

To Compute Length of a Side.

When Hypotenuse of a Right-angled Triangle of Equal Sides alone is given.—Fig. 8. RULE.—Divide hypotenuse by 1.414 213.

Or, $\frac{hyp.}{1.414213} =$ *length of a side.*

Fig. 8.



EXAMPLE.—Hypotenuse *a c* of a right-angled triangle, Fig. 8, is 300 feet; what is length of its sides?

$300 \div 1.414\,213 = 212.1321$ *feet.*

To Compute Perpendicular or Height of a Triangle.

When Base and Area alone are given.—Fig. 9. RULE.—Divide twice [illegible] by its base. Or, $2a \div b = h$.

[illegible] of a triangle, Fig. 9, is 10 feet, and length of its base, *a b*, 5; [illegible]ular, *c d*?

$10 \times 2 = 20$, and $20 \div 5 = 4$ *feet.*

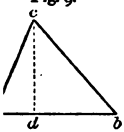
ɔ Compute Perpendicular or Height of a Triangle.

When Base and Two Sides are given. RULE.—As base is to sum of the .es, so is difference of sides to difference of divisions of base. Half this ference being added to or subtracted from half base will give the two di- ıions thereof. Hence, as the sides and their opposite division of base con- tute a right-angled triangle, the perpendicular thereof is readily ascertained preceding rules.

$$\text{Or, } \frac{bc + ca \times \overline{bc \sim ca}}{ba} = bd \sim da.$$

$$\text{Or, } \frac{ac^2 + ab^2 - bc^2}{2ab} = ad; \text{ whence } \sqrt{ac^2 - ad^2} = dc.$$

Fig. 9.



EXAMPLE.—Three sides of a triangle, $a\,b\,c$, Fig. 9, are 9.928, 8, and 5 feet; what is length of perpendicular on longest side?

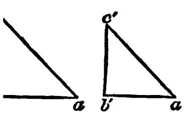
As $9.928 : 8 + 5 :: 8 \sim 5 : 3.928 =$ *difference of divisions of the base.*

Then $3.928 \div 2 = 1.964$, which, added to $\frac{9.928}{2} = 4.964 + 1.964 = 6\,928 =$ *length of longest division of base.*

Hence, there is a right-angled triangle with its base 6.928, and its hypotenuse 8; ısequently, its remaining side or perpendicular is $\sqrt{(8^2 - 6.928^2)} = 4$ *feet.*

hen any Two of the Dimensions of a Triangle and One of the corresponding Dimensions of a similar Figure are given, and it is required to ascertain the other corresponding Dimensions of the last Figure.

Fig. 10. Fig. 11.



Let $a\,b\,c$, $a'\,b'\,c'$, be two similar triangles, Figs. 10 and 11.

Then $ab : bc :: a'b' : b'c'$, or $a'b' : b'c' :: ab : bc$.

NOTE.—Same proportion holds with respect to the similar lineal parts of any other similar figures, whether plane or solid.

EXAMPLE.—Shadow of a vertical stake 4 feet in length was 5 feet; at same time, ıdow of a tree, both on level ground, was 83 feet; what was height of tree?

$$5\ a'b' : 4\ b'c' :: 83\ ab : 66.4 \textit{ feet.}$$

To Compute Acreage.

Divide area into convenient triangles, and multiply base of each triangle links by half perpendicular in links; cut off 5 figures at the *right*, remain- ; figures will give acres; multiply the 5 figures so cut off by 4, and again t off 5, and remainder will give roods; multiply the 5 by 40, and again t off 5 for perches.

Trapezium.

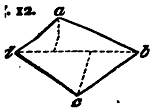
DEFINITION.—A Quadrilateral having unequal sides of which no two are parallel.

To Compute Area of a Trapezium.—Fig. 12.

RULE.—Multiply diagonal by sum of the two perpendiculars falling upon from the opposite angles, and divide product by 2.

$$\text{Or, } \frac{db \times \overline{a + c}}{2} = area.$$

. 12.



EXAMPLE.—Diagonal $d\,b$, Fig. 12, is 125 feet, and perpen diculars a and c 50 and 37; what is area?

$$125 \times \overline{50 + 37} = 10875, \text{ and } 10875 \div 2 = 5437.5$$

When the Two opposite Angles are Supplements to each other, that is, a Trapezium can be inscribed in a Circle, the Sum of its opposite An being equal to Two Right Angles, or 180°. RULE.—From half sum of four sides, subtract each side severally; then multiply the four remain continually together, and take square root of product.

EXAMPLE.—In a trapezium the sides are 15, 13, 14, and 12 feet; its opposite gles being supplements to each other, required its area.

$$15+13+14+12=54, \text{ and } \frac{54}{2}=27.$$

$$\begin{array}{cccc} 27 & 27 & 27 & 27 \\ 15 & 13 & 14 & 12 \\ \hline 12 \times & 14 \times & 13 \times & 15 = 32\,760, \end{array} \text{ and } \sqrt{32\,760}=180.997 \textit{ square feet.}$$

Trapezoid.

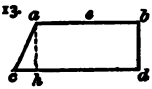
DEFINITION.—A Quadrilateral with only one pair of opposite sides parallel.

To Compute Area of a Trapezoid.—Fig. 13.

RULE.—Multiply sum of the parallel sides by perpendicular distance tween them, and divide product by 2.

$$\text{Or, } \frac{ab+dc \times ah}{2}. \quad \text{Or, } \frac{s+s' \times h}{2} = \textit{area, s and s' representing sides.}$$

Fig. 13.



EXAMPLE.—Parallel sides $a\,b$, $c\,d$, Fig. 13, are 100 an feet, and distance between them 62.5 feet; what is ar

$100+132 \times 62.5 = 14\,500$, and $14\,500 \div 2 = 7250$ sq *feet.*

Polygons.

DEFINITION.—Plane figures having three or more sides, and are either regul irregular, according as their sides or angles are equal or unequal, and they are na from the number of their sides and angles.

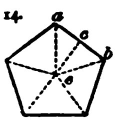
Regular Polygons.

To Compute Area of a Regular Polygon.—Fig. 14

RULE.—Multiply length of a side by perpendicular distance to cen multiply product by number of sides, and divide it by 2.

$$\text{Or, } \frac{ab \times ce \times n}{2} = \textit{area, n representing number of sides.}$$

Fig. 14.



EXAMPLE.—What is area of a pentagon, side $a\,b$, Fig. 14, b 5 feet, and distance $c\,e$ 4.25 feet?

$5 \times 4.25 \times 5\,(n) = 106.25 =$ *product of length of a side, tance to centre, and number of sides.*

Then, $106.25 \div 2 = 53.125$ *square feet.*

To Compute Radius of a Circle that contains a Gi Polygon.

When Length of a Perpendicular from Centre alone is given. Ru Multiply distance from centre to a side of the polygon, by unit in colu of following Table.

EXAMPLE.—What is radius of a circle that contains a hexagon, distance to being 4.33 inches?

$$4.33 \times 1.156 = 5 \textit{ ins.}$$

To Compute Length of a Side of a Polygon that is c tained in a Given Circle.

Radius of Circle is given. RULE.—Multiply radius of circ umn B of following Table.

—What is length of side of a pentagon contained in a circle 8.5

$$8.5 \div 2 = 4.25 \text{ radius, and } 4.25 \times 1.1756 = 5 \text{ feet.}$$

To Compute Radius of a Circumscribing Circle.

When Length of a Side is given. RULE.—Multiply length of a side of the lygon, by unit in column C of following Table.

EXAMPLE.—What is radius of a circle that will contain a hexagon, a side being 5 hes?

$$5 \times 1 = 5 \textit{ ins.}$$

o Compute Radius of a Circle that can be Inscribed in a Given Polygon.

When Length of a Side is given. RULE.—Multiply length of a side of lygon, by unit in column D of following Table.

EXAMPLE.—What is radius of the circle that is bounded by a hexagon, its sides ing 5 inches?

$$5 \times .866 = 4.33 \textit{ ins.}$$

To Compute Area of a Regular Polygon.

When Length of a Side only is given. RULE.—Multiply square of side, multiplier opposite to term of polygon in following Table:

o. of ides.	POLYGON.	AREA.	A. Radius of Circumscribed Circle.	B. Length of a Side.	C. Radius of Circumscribing Circle.	D. Radius of Inscribed Circle.
3	Trigon	.43301	2	1.732	.5773	.2887
4	Tetragon	1	1.414	1.4142	.7071	.5
5	Pentagon	1.72048	1.238	1.1756	.8506	.6882
6	Hexagon	2.59808	1.156	1	1	.866
7	Heptagon	3.63391	1.11	.8677	1.1524	1.0383
8	Octagon	4.82843	1.083	.7653	1.3066	1.2071
9	Nonagon	6.18182	1.064	.684	1.4619	1.3737
10	Decagon	7.69421	1.051	.618	1.618	1.5388
11	Undecagon	9.36564	1.042	.5634	1.7747	1.7028
12	Dodecagon	11.19615	1.037	.5176	1.9319	1.866

EXAMPLE. — What is area of a square (tetragon) when length of its sides is 71 067 8 inches?

$$7.071\,067\,8^2 = 50, \text{ and } 50 \times 1 = 50 \textit{ square ins.}$$

o Compute Length of a Side and Radii of a Regular Polygon.

When Area alone is given. RULE.—Multiply square root of area of polyn by multiplier in column E of the following table for length of side; by ltiplier in column G for radius of circumscribing circle, and by multiplier column H for radius of inscribed circle or perpendicular.

. of es.	POLYGON.	E. Length of Side.	G. Radius of Circumscribing Circle.	H. Radius of Inscribed Circle.	Angle.	Angle of Polygon.	Tangent.
3	Trigon	1.5197	.8774	.4387	120°	60°	.5774
4	Tetragon	1	.7071	.5	90	90	1
5	Pentagon	.7624	.6485	.5247	72	108	1.3764
6	Hexagon	.6204	.6204	.5373	60	120	1.7321
7	Heptagon	.5246	.6045	.5446	51 25.71′	128 34.29′	2.0765
8	Octagon	.4551	.5946	.5493	45	135	2.4142
9	Nonagon	.4022	.588	.5525	40	140	2.7475
10	Decagon	.3605	.5833	.5548	36	144	3.0777
11	Undecagon	.3268	.5799	.5564	32 43.64′	147 16.36′	3.4057
12	Dodecagon	.2989	.5774	.5577	30	150	3.7321

XAMPLE 1.—*Area of a square (tetragon)* is 16 inches; what is

$$\sqrt{16} = 4, \text{ and } 4 \times 1 = 4 \textit{ ins.}$$

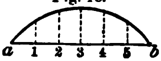
—*Area of an octagon* is *70.698* yards; what is diameter

$$\sqrt{70.698} \times .5946 = 5, \text{ and } 5 \times 2 = 10 \text{ yards}$$

To Compute an Area bounded by a Curve.—Fig. 18.

(*Simpson's Rule.*)

Fig. 18.



OPERATION.—Divide line *a b* into any number of *equal* parts, by perpendiculars from base, as 1, 2, 3, etc., which will give an *odd* number of points of division. Measure lengths of these perpendiculars or ordinates, and proceed as follows:

To sum of lengths of first and last ordinates, add four times sum of lengths of all even numbered ordinates and twice sum of odd; multiply their sum by one third of distance between ordinates, and product will give area required.

ILLUSTRATION.—Water-line of a vessel has a length of 80 feet, and ordinates 0, 1, 1.2, 1.5, 2, 1.9, 1.5, 1.1, and 0, each 10 feet apart; what is its area?

Ordinates.

Even.	Odd.	Sums.
1	1.2	first 0
1.5	2	last 0
1.9	1.5	even 22
1.1		odd 9.4
5.5 × 4 = 22.	4.7 × 2 = 9.4	31.4 × 10 = 314, which ÷ 3 = 104.66 *square feet.*

Circle.

Diameter is a right line drawn through its centre, bounded by its periphery.

Radius is a right line drawn from its centre to its circumference.

Circumference is assumed to be divided into 360 equal parts, termed *degrees;* each degree is divided into 60 parts, termed *minutes;* each minute into 60 parts, termed *seconds;* and each second into 60 parts, termed *thirds*, and so on.

To Compute Circumference of a Circle.

RULE.—Multiply diameter by 3.1416.

Or, as 7 is to 22, so is diameter to circumference.

Or, as 113 is to 355, so is diameter to circumference.

EXAMPLE.—Diameter of a circle is 1.25 inches; what is its circumference?

1.25 × 3.1416 = 3.927 *ins.*

To Compute Diameter of a Circle.

RULE.—Divide circumference by 3.1416.

Or, as 22 is to 7, so is circumference to diameter.

NOTE.—Divide area by .7854, and square root of quotient will give diameter of circle.

To Compute Area of a Circle.

RULE.—Multiply square of diameter by .7854.

Or, multiply square of circumference by .079 58.

Or, multiply half circumference by half diameter.

Or, multiply square of radius by 3.1416.

Or, $p\ r^2 = area$, *r representing radius.*

EXAMPLE.—The diameter of a circle is 8 inches; what is the area of it?

$8^2 = 64$, and 64 × .7854 = 50.2656 *ins.*

Proportions of a Circle, its Equal, Inscribed, and Circumscribed Squares.

CIRCLE.

1. Diameter × .8862 } = Side of an Equal Square.
2. Circumference × .2821 }
3. Diameter × .7071 }
4. Circumference × .2251 } = Side of Inscribed Square.
5. Area × .9003 ÷ diam. }
6. Diameter × 1.3468 = Side of an Equilateral Triangle.

SQUARE.

A Side × 1.1442 = Diameter of its Circumscribing Circle.
" 442 = Circumference of its Circumscribing Circle.
= Diameter }
= Circumference } of an Equal Circle.
= Circle inches }

thin a circle is one half area of one described without

To Compute Side of Greatest Square that can be Inscribed in a Circle.

RULE.—Multiply diameter by .7071, or take twice square of radius.

Useful Factors.

In which p or π represents Circumference of a Circle.

Diameter = 1.

$p = 3.141\,592\,653\,589+$	$\frac{4}{3}\,p = 4.188\,79+$	$\sqrt{p} = 1.772\,453$
$2\,p = 6.283\,185\,307\,179+$	$\frac{1}{6}\,p = .523\,598+$	$\sqrt{\frac{2}{p}} = .797\,884$
$4\,p = 12.566\,370\,614\,359+$	$\frac{1}{8}\,p = .392\,699+$	Log. $p = .497\,149\,87$
$\frac{1}{2}\,p = 1.570\,796\,326\,794+$	$\frac{1}{12}\,p = .261\,799+$	$\frac{1}{2}\sqrt{p} = .886\,226+$
$\frac{1}{4}\,p = .785\,398\,163\,397+$	$\frac{1}{360}\,p = .008\,726+$	$36\,p = 113.097\,335+$

Diameter = 10.

1. Chord of arc of semicircle	= 10
2. Chord of half arc of semicircle	= 7.071 067
3. Versed sine of arc of semicircle.	= 5
4. Versed sine of half arc of semicircle	= 1.464 466
5. Chord of half arc, of half of arc of semicircle	= 3.826 83
6. Half chord, of chord of half arc	= 3.535 533
7. Length of arc of semicircle	= 15.707 963
8. Length of half arc of semicircle	= 7.853 981
9. Square of chord, of half arc of semicircle (2)	= 50
10. Square root of versed sine of half arc (4)	= 1.210 151
11. Square of versed sine of half arc (4)	= 2.144 664
12. Square of chord of half arc, of half arc of semicircle (5)	= 14.644 67
13. Square of half chord, of chord of half arc (6)	= 12.5

NOTE.—In all computations p is taken at 3.1416, $\frac{1}{4}\,p$ at .7854, $\frac{1}{6}\,p$ at .5236; and whenever the decimal figure next to the one last taken exceeds 5, one is added. Thus, 3.141 59 for four places of decimals is taken as 3.1416.

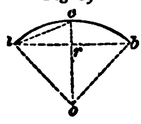
To Compute Length of an Arc of a Circle.—Fig. 19.

When Number of Degrees and Radius are given. RULE 1.—Multiply number of degrees in the arc by 3.1416 times the radius, and divide by 180.

2.—Multiply radius of circle by .017 453 29, and product by degrees in the arc.

If length is required for minutes, multiply radius by .000 290 889; if for seconds, by .000 004 848.

Fig. 19.



EXAMPLE 1.—Number of degrees in an arc, $o\,a\,b$, Fig. 19, are 90, and radius, $o\,b$, 5 inches; what is length of arc?

$90 \times (3.1416 \times 5) = 1413.72$, which $\div\, 180 = 7.854$ *ins.*

2.—Radius of an arc is 10, and measure of its angle 44° 30′ 30″; what is length of arc?

$10 \times .017\,453\,29 = .174\,532\,9$, which $\times\, 44 = 7.679\,447\,6$, *length for* 44°.

$10 \times .000\,290\,889 = .002\,908\,89$, which $\times\, 30 = .087\,266\,7$, *length for* 30′.
$10 \times .000\,004\,848 = .000\,048\,48$, which $\times\, 30 = .001\,454\,4$, *length for* 30″.

$$\text{Then } \left.\begin{array}{r} 7.679\,447\,6 \\ .087\,266\,7 \\ .001\,454\,4 \end{array}\right\} = 7.768\,168\,7 \textit{ ins.}$$

Or, reduce minutes and seconds to decimal of a degree, and multiply

See Rule, page 93. 30′ 30″ = .5083, and .174 532 9 from above
68 163 ins.

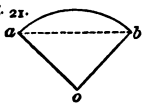
Sector of a Circle.

DEFINITION.—A part of a circle bounded by an arc and two radii.

To Compute Area of a Sector of a Circle.

When Degrees in the Arc are given.—Fig. 21. RULE.—As 360 is to number of degrees in a sector, so is area of circle of which sector is a part to area of sector.

Fig. 21.



Or, $\frac{d\,a}{360}$ = *area, d representing degrees in arc, and a area of circle.*

EXAMPLE.—Radius of a circle, $o\,a$, Fig. 21, is 5 ins., and number of degrees of sector, $a\,b\,o$, is 22° 30′; what is area?

Area of a circle of 5 ins. radius = 78.54 ins.

Then, as 360° : 22° 30′ :: 78.54 : 4.90875 *ins.*

When Length of the Arc, etc., are given. RULE.—Multiply length of arc by half length of radius, and product is area.

Or, $b \times \overline{r \div 2}$ = *area, b representing arc, and r radius.*

Segment of a Circle.

DEFINITION.—A part of a circle bounded by an arc and a chord.

To Compute Area of a Segment of a Circle.

When Chord and Versed Sine of Arc, and Radius or Diameter of Circle are given.

When Segment is less than a Semicircle, as a b c, Fig. 21. RULE.—Ascertain area of sector having same arc as segment; then ascertain area of triangle formed by chord of segment and radii of sector, and take difference of these areas.

NOTE.—Subtract versed sine from radius; multiply remainder by one half of chord of arc, and product will give area of triangle.

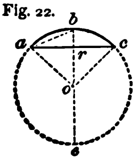
Or, $a - a'$ = *area, a and a′ representing areas of sector and triangle.*

When Segment is greater than a Semicircle. RULE.—Ascertain, by preceding rule, area of lesser portion of circle; subtract it from area of whole circle, and remainder will give area.

Or, $a - a'$ = *area, a and a′ representing areas of circle and lesser portion.*

See Table of Areas of Segments, page 267.

Fig. 22.



EXAMPLE.—Chord, $a\,c$, Fig. 22, is 14.142; diameter, $b\,e$, is 20 ins.; and versed sine, $b\,r$, is 2.929; what is area of segment?

14.142 ÷ 2 = 7.071 = *half chord of arc.*

$\sqrt{7.071^2 + 2.929^2} = 7.654$ = *square root of sum of squares of half chord of arc and versed sine, which is chord a b of half arc a b c.*

By Rule, page 344,

7.654 × 2 × 2.929 × 10 = 448.371 = *twice chord of half arc by 10 times versed sine.*

$\overline{60} - \overline{2.929 \times 27}$ = 1120.917 = 60 *times diameter subtracted from 27 times sine.*

448.371 ÷ 1120.917 = .4, and .4 added to $\overline{7.654 \times 2}$ (twice chord of half arc) *length of arc.*

$\frac{10}{2}$ = 78.54 = *the arc multiplied by half length of radius,*

sine subtracted from a radius, which is height of triangle.

When the Chords of Arc, and of half of Arc, and Versed Sine are given. RULE.—To chord of whole arc add chord of half arc and one third of it more; multiply this sum by versed sine, and this product, multiplied by .404 26, will give area nearly.

$$\text{Or, } c + c' + \frac{c'}{3}\, v.\ sin. \times .404\,26 = area\ nearly.$$

EXAMPLE.—Chord of a segment, *a c*, Fig. 22, is 28 feet; chord of half arc, *a b*, is 15; and versed sine, *b r*, 6; what is area of segment?

$28 + 15 + \frac{15}{3} =$ *chord of arc added to chord of half arc and one third of it more.*
$48 \times 6 = 288 =$ *product of above sum and versed sine.* Hence $288 \times .404\,26 = 116.427$ *square feet.*

When the Chord of Arc and Versed Sine only are given. RULE.—Ascertain chord of half arc, and proceed as before.

To Compute Chord and Height of a Segment of a Circle.

When Area is given. RULE.—Divide area by square of diameter of circle, take tab. height for area from table of Areas of Segments of a Circle, p. 267, multiply it by diameter, and product will give required height.

From diameter subtract height, multiply remainder by height, take square root of product and multiply it by 2 for required chord.

$$\text{Or, } \frac{a}{d^2} = (tab.\ area\ for\ height) \times d = h, \text{ and } \sqrt{d - h \times h} \times 2 = c.$$

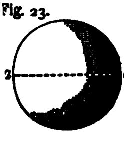
Circular Measure. (See Rule, page 113.)

Sphere.

DEFINITION.—A figure, surface of which is at a uniform distance from centre.

To Compute Convex Surface of a Sphere.—Fig. 23.

Fig. 23.



RULE.—Multiply diameter by circumference, and product will give surface.

$$\text{Or, } 4\, p\, r^2 = surface.\text{*} \quad \text{Or, } p\, d^2 = surface.$$

EXAMPLE.—What is convex surface of a sphere, Fig. 23, having a diameter, *a b*, of 10 ins?

$10 \times 31.416 = 314.16$ *square ins.*

Segment of a Sphere.

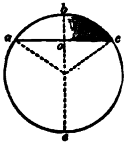
DEFINITION.—A section of a sphere.

To Compute Surface of a Segment of a Sphere.—Fig. 24.

RULE.—Multiply height by the circumference of sphere, and add product to the area of base.

$$\text{Or, } 2\, p\, r\, h = convex\ surface\ alone.$$

Fig. 24.



EXAMPLE.—Height, *b o*, of a segment, *a b c*, Fig. 24, is 36 ins., and diameter, *b e*, of sphere 100; what is convex surface, and what whole surface?

$36 \times 100 \times 3.1416 = 11\,309.76 =$ *height of segment multiplied by circumference of sphere.*

To ascertain area of base; diameter and versed sine being given, diameter of base of segment, being equal to chord of arc, is, by Rule, page 344,

$$100 - 36 \times 2 = 28, \quad \sqrt{100^2 - 28^2} = 96.$$

$96^2 \times .7854 = 7238.2464 =$ *convex surface*, and $7238.2464 + 11\,309.76 = 18\,548.006$ = *convex surface added to area of base = square ins.*

NOTE.—*When convex surface of a figure alone is required, area of ends must be omitted.*

* *p or π represents in this, and in all cases where it is used, ratio of circumference to diameter, or 3.1416.*

When the Diameter of Base of Segment and Height of it are alone given. RULE.—Add square of half diameter of base to the square of height; divide this sum by height, and result will give diameter of sphere.

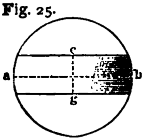
$$\text{Or, } \overline{d \div 2}^{\,2} + h^2 \div h = diameter.$$

Spherical Zone (or Frustum of a Sphere).

DEFINITION.—The part of a sphere included between two parallel chords.

To Compute Surface of a Spherical Zone.—Fig. 25.

Fig. 25.



RULE.—Multiply height by the circumference of sphere, and add product to area of the two ends.

$$\text{Or, } h\,c + a + a' = surface.$$
$$\text{Or, } 2\,p\,r\,h = convex\ surface\ alone.$$

EXAMPLE. — Diameter of a sphere, $a\,b$, Fig. 25, from which a zone, $c\,g$, is cut, is 25 inches, and height, $c\,g$, is 8; what is convex surface?

$$25 \times 3.1416 \times 8 = 628.32 = height \times circumference\ of\ sphere = square\ ins.$$

When the Diameter of Sphere is not given. RULE.—Multiply mean length of the two chords by half their difference; divide this product by breadth of zone, and to quotient add breadth. To square of this sum add square of lesser chord, and square root of their sum will give diameter of sphere.

$$\text{Or, } \sqrt{\left(\overline{\frac{l+l'}{2} \times \frac{l \sim l'}{2} \div b + b}^{\,2} + l'^2\right)} = d.$$

Spheroids or Ellipsoids.

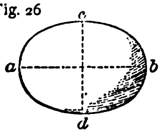
DEFINITION.—Figures generated by the revolution of a semi-ellipse about one of its diameters.

When revolution is about Transverse diameter they are Prolate, and when it is about Conjugate they are Oblate.

To Compute Surface of a Spheroid.—Fig. 26.

When Spheroid is Prolate. RULE. — Square diameters, and multiply square root of half their sum by 3.1416, and this product by conjugate diameter.

Fig. 26



Or, $\sqrt{\frac{d^2+d'^2}{2}} \times 3.1416 \times d = surface$, *$d$ and d' representing conjugate and transverse diameters.*

EXAMPLE.—A prolate spheroid, Fig. 26, has diameters, $c\,d$ and $a\,b$, of 10 and 14 inches; what is its surface?

$$10^2 + 14^2 = 296 = sum\ of\ squares\ of\ diameters.$$

$296 \div 2 = 148$, and $\sqrt{148} = 12.1655 =$ *square root of half sum of squares of diameters.*

$12.1655 \times 3.1416 \times 10 = 382.191$ *ins. = product of root above obtained* $\times$ 3.1416, *conjugate diameter.*

When Spheroid is Oblate. RULE.—Square diameters, and multiply square root of half their sum by 3.1416, and this product by transverse diameter.

$$\text{Or, } \sqrt{\frac{d^2+d'^2}{2}} \times 3.1416 \times d' = surface.$$

An oblate spheroid has diameters of 14 and 10 inches; what is its

296 = *sum of squares of diameters.*

12.1655 = *square root of half sum of squares of di-*

above obtained $\times$ 3.1416,

To Compute Convex Surface of a Segment of a Spheroid.—Figs. 27 and 28.

RULE.—Square diameters, and take square root of half their sum; then, as diameter from which the segment is cut is to this root, so is the height of segment to proportionate height required. Multiply product of other diameter and 3.1416 by proportionate height of segment, and this last product will give surface.

$$\text{Or, } \frac{\sqrt{d^2 + d'^2 \div 2}}{d \text{ or } d'} \times h \times d' \text{ or } d \times 3.1416 = surface.$$

Fig. 27.

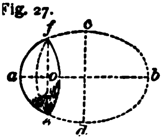
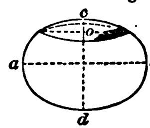


Fig. 28.



EXAMPLE. — Height, $a\ o$, of a segment, $e\ f$, of a prolate spheroid, Fig. 27, is 4 inches, diameters being 10 and 14; what is convex surface of it?

Square root of half sum of squares of diameters, 12.1655.

Then 14 : 12.1655 :: 4 : 3.4758 = *height of segment, proportionate to mean of diameters, and* 10 × 3.1416 × 3.4758 = 109.1957 *ins.*

2.—Height, $c\ o$, of a segment of an oblate spheroid, Fig. 28, is 4 inches, the diameters being 14 and 10; what is convex surface of it? 214.0272 *square ins.*

To Compute Convex Surface of a Frustum or Zone of a Spheroid.—Figs. 29 and 30.

RULE.—Proceed as by previous rule for surface of a segment, and obtain proportionate height of frustum; then multiply product of diameter parallel to base of frustum and 3.1416 by proportionate height of frustum, and it will give surface.

Fig. 29.

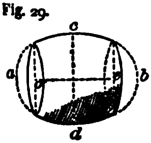
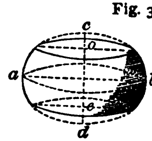


Fig. 30.



EXAMPLE.—Middle frustum, $o\ e$, of a prolate spheroid, Fig. 29, is 6 inches, diameters of spheroid being 10 and 14; what is its convex surface?

Mean diameter, as per preceding example, is 12.1655.

Diameter parallel to base of frustum is 10.

Then 14 : 12.1655 :: 6 : 5.2138, and 10 × 3.1416 × 5.2138 = 163.7967 *square ins.*

2.—Middle frustum of an oblate spheroid, as $o\ e$, Fig. 30, is 2 inches in height, diameters of spheroid, as in preceding examples, being 10 and 14; what is its convex surface? 107.0136 *square ins.*

Circular Zone.

DEFINITION.—A part of a circle included between two parallel chords.

To Compute Area of a Circular Zone.

RULE.—From area of circle subtract areas of segments.

Or, see Table of Areas of Zones, page 269.

When Diameter of Circle is not given.—Multiply mean length of the two chords by half their difference; divide this product by breadth of zone, and to quotient add the breadth.

To square of this sum add square of lesser chord, and square root of their sum will give diameter of circle.

EXAMPLE.—Greater chord, $h\ g$, is 90 inches; lesser, $a\ c$, is 80; and breadth, e, is 72.526; what is its diameter?

$$\frac{80+90}{2} \times \frac{90 \sim 80}{2} = 85 \times 5 = 425, \text{ and } \frac{425}{72.526} + 72.526 = 78.3$$

$$\text{Then } \sqrt{78.385^2 + 80^2} = \sqrt{12544.2} = 112 = diameter.$$

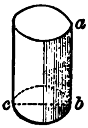
Cylinder.

DEFINITION.—A figure formed by revolution of a right-angled parallelogram around one of its sides.

To Compute Surface of a Cylinder.—Fig. 31.

RULE.—Multiply length by circumference, and add product to area of the two ends.

Fig. 31.



Or, $l\,c + 2\,a = s$, *a representing area of end.*

NOTE.—When internal or convex surface alone is wanted, areas of ends are omitted.

EXAMPLE.—Diameter of a cylinder, *b c*, Fig. 31, is 30 inches, and its length, *a b*, 50; what is its surface?

$30 \times 3.1416 = 94.248$, and $94.248 \times 50 = 4712.4$.

Then $30^2 \times .7854 = 706.86$ = *area of one end;* $706.86 \times 2 = 1413.72$ = *area of both ends*, and $4712.4 + 1413.72 = 6125.12$ *square ins.*

Prisms.

DEFINITION.—Figures, sides of which are parallelograms, and ends equal and parallel.

NOTE.—When ends are triangles, they are termed *triangular prisms;* when they are square, *square* or *right prisms;* and when they are a pentagon, *pentagonal prisms*, etc.

To Compute Surface of a Right Prism.—Figs. 32 and 33.

Fig. 32.

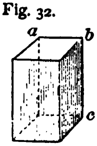
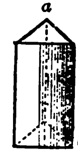


Fig. 33.



RULE.—Ascertain areas of ends and sides, and add them together.

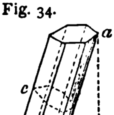
Or, $2\,a + n\,a' = s$, *a representing area of ends, a' area of sides, and n their number.*

EXAMPLE.—Side, *a b*, Fig. 32, of a square prism is 12 inches, and length, *b c*, 30; what is surface?

$12 \times 12 = 144$ = *area of one end;* $144 \times 2 = 288$ = *area of both ends;* $12 \times 30 = 360$ = *area of one side;* $360 \times 4 = 1440$ = *area of four sides*, and $288 + 1440 = 1728$ *sq. ins.*

To Compute Surface of an Oblique or Irregular Prism.—Fig. 34.

Fig. 34.



RULE.—Multiply perimeter of one end, by perpendicular height, *a o*. Or, multiply perimeter as at *c*, at a right angle to sides by actual length of figure, and add area of ends.

EXAMPLE.—Sides, *a c*, of an oblique hexagonal prism, Fig. 34, are 10 inches, and perpendicular height, *a o*, is 5 feet; what is its surface?

$10 \times 6 = 60$ *ins.* = *length of sides.*

$60 \times \overline{5 \times 12} = 3600$ *square ins.* = *area of sides*, and by table, page 339, $100 \times 2.59808 \times 2 = 519.616$ *square ins., which added to* $3600 = 4119.616$ *square ins.*

Wedge.

DEFINITION.—A wedge is a prolate triangular prism, and its surface is computed e for that of a right prism.

To Compute Surface of a Wedge.—Fig. 35.

EXAMPLE.—Back of a wedge, *a b c d*, Fig. 35, is 20 by 2 inches, and its end, *e f*, 20 by 2; what is its surface?

$20^2 + \overline{2 - 1}^2 = 401$ = *sum of squares of half base, a f, and height, e f, of triangle, e f a.*

$= 20.025$ = square root of above sum = length of e a.

Then $20.025 \times 20 \times 2 = 801$ = area of sides.

$\times 2 = 40$ = area of back; and $2c \times \overline{2 \div 2} \times 2 = 40 =$

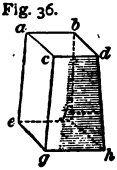
$+ 40 = 881$ square ins.

Prismoids.

Definition.—Figures alike to a prism, having only one pair of sides parallel.

To Compute Surface of a Prismoid.—Fig. 36.

Fig. 36.



Rule.—Ascertain area of sides and ends as by rules for squares, triangles, etc., and add them together.

Example.—Ends of a prismoid, $e f g h$ and $a b c d$, Fig. 36, are 10 and 8 inches square, and its slant height, $d h$, 25; what is its surface?

$10 \times 10 = 100 =$ *area of base*; $8 \times 8 = 64 =$ *area of top*.

$\frac{10+8}{2} \times 25 = 225$, and $225 \times 4 = 900 =$ *area of sides*.

Then $100 + 64 + 900 = 1064 =$ *square ins.*

To Compute Surface of an Oblique or Irregular Prismoid.

Proceed as directed for an Oblique or Irregular Prism, page 350.

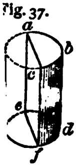
Ungulas.

Definition.—Cylindrical ungulas are the parts (including all or part of the base) left by a plane cutting a cylinder through any portion and at any angle.

To Compute Curved Surface of an Ungula.—Figs. 37, 38, 39, and 40.

When Section is parallel to Axis of the Cylinder, Fig. 37. Rule 1.—Multiply length of arc of one end by height.

Fig. 37.

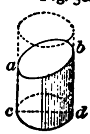


Example.—Diameter of a cylinder, $a\ c$, from which an ungula, Fig. 37, is cut, is 10 inches, its length, $b\ d$, 50, and versed sine or depth of ungula is 5 inches; what is curved surface?

$10 \div 2 = 5 =$ *radius of cylinder.*

Hence radius and versed sine are equal; the arc, therefore, of ungula is one half circumference of the cylinder, which is $31.416 \div 2 = 15.708$, and $15.708 \times 50 = 785.4$ *square ins.*

Fig. 38.



When Section passes obliquely through opposite Sides of Cylinder, Fig. 38. Rule 2.—Multiply circumference of base of cylinder by half sum of greatest and least heights of ungula.

Example.—Diameter, $c\ d$, of a cylindrical ungula, Fig. 38, is 10 inches, and greatest and less heights, $b\ d$ and $a\ c$, are 25 and 15 inches; what is its curved surface?

10 *diameter* $= 31.416$ *circumference*; $25 + 15 = 40$, and $40 \div 2 = 20$. Hence $31.416 \times 20 = 628.32$ *square ins.*

When Section passes through Base of Cylinder and one of its Sides, and Versed Sine does not exceed Sine, or Base is equal to or less than a Semicircle, Fig. 39. Rule 3.—Multiply sine, $a\ d$, of half arc, $d\ g$, of base, $d\ g\ f$, by diameter, $e\ g$, of cylinder, and from this product subtract product* of arc and cosine, $a\ o$. Multiply difference thus found by quotient of height, $g\ c$, divided by versed sine, $a\ g$.

Note.—The *sine of base* is half of the longest chord that can be drawn in base.

Fig. 39.

Example.—Sine, $a\ d$, of half arc of base of an ungula, Fig. 39, is 5, diameter of cylinder, $e\ g$, is 10, and height, $c\ g$, of ungula 10 inches; what is curved surface?

$5 \times 10 = 50 =$ *sine of half arc by dia*

Length of arc, versed sine and radius being e ... page 346 $= 15.708$, and as versed sine and radius are e

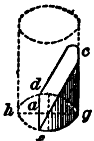
Hence, when cosine is o, product is o. Then *ference of product before obtained and product*

$50 \times 10 \div 5 = 50 \times 2 = 100$ *square ins.*

* When the cosine is o, this product is o.

When Section passes through Base of Cylinder, and Versed Sine, a g ex-ceeds Sine, or when Base exceeds a Semicircle, Fig. 40. RULE 4.—Mul

Fig. 40.



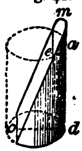
sine of half the arc of base by diameter of cylinder, and to product add product of arc and the excess of versed sine the sine of base. Multiply sum thus found by quotie height divided by versed sine.

EXAMPLE.—Sine, *a d*, of half arc of an ungula, Fig. 40, is 12 in versed sine, *a g*, is 16; height, *c g*, 16; and diameter of cylinde 25 inches; what is curved surface?

$12 \times 25 = 300 =$ *sine of half arc by diameter of cylinder*, and l of arc of base, Rule, page 344 = *arc of d h f — circumference of b* 46.392.

Then $46.392 \times \overline{16 - 12.5} = 162.372$, and $300 + 162.272 = 462.372$; $16 \div 16 = 1$ $462.372 \times 1 = 462.372$ *square ins.*

Fig. 41.



NOTE.—When sine of an arc is 0, the versed sine is equal to dian

When Section passes obliquely through both Ends of Cyli Fig. 41. RULE 5.—Conceive section to be continued to *m*, meets side of cylinder produced; then, as difference of v sines, *a e* and *d o*, of arcs of two ends of ungula is to versed *a e*, of arc of the less end, so is height of cylinder, *a d*, t part of side produced.

Ascertain surface of each of ungulas thus found by Ru and 4, and their difference will give curved surface.

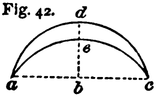
Lune.

DEFINITION.—Space between intersecting arcs of two eccentric circles.

To Compute Area of a Lune.—Fig. 42.

RULE.—Ascertain areas of the two segments from which lune is for and their difference will give area.

Fig. 42.



EXAMPLE.—Length of chord *a c*, Fig. 42, is 20 inches, h *e d* is 3, and *e b* 2; what is area of lune?

By Rule 2, page 345, diameters of circles of which lu formed are thus ascertained:

For *a d c*, $\frac{10^2 + (3+2)^2}{5} = 25$. For *a e c*, $\frac{10^2 + 2^2}{2} =$

Then, by Rule for Areas of Segments of a Circle, page 267,

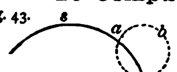
Area of *a d c* is 70.5577 *sq. ins.*
" *a e c* " 27.1638 "
Their difference 43.3939 *sq. ins.*

Cycloid.

DEFINITION.—A curve generated by revolution of a circle on a plane.

To Compute Area of a Cycloid.—Fig. 43.

Fig. 43.



RULE.—Multiply area of generating circle b

EXAMPLE.—Generating circle of a cycloid, *a b c*, Fig has an area of 115.45 sq. inches; what is area of cycl

$115.45 \times 3 = 346.35$ *square ins.*

o Compute Length of a Cycloidal Curve.

-Multiply diameter of generating circle by 4.

meter of generating circle of a cycloid, Fig. 43, is 8 inches; w

= *product of diameter and* 4 = *ins.*

loid is line of swiftest descent; that is, a body will m one point to another, in less time than through

Circular Rings.

Definition.—Space between two concentric circles.

ℸo Compute Sectional Area of a Circular Ring.—Fig. 44.

Rule.—From area of greater circle subtract that of less.

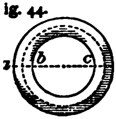
Cylindrical Rings.

Definition.—A ring formed by curvature of a cylinder.

To Compute Surface of a Cylindrical Ring.—Fig. 44.

Rule.—To diameter of body of the ring add inner diameter of the ring; ıultiply this sum by diameter of the body, and product by 9.8696.

ig. 44.



Or, $c \times l =$ *surface.*

Example.—Diameter of body of a cylindrical ring, *a b*, Fig. 44, is 2 inches, and inner diameter, *b c*, is 18; what is surface of it?

$2 + 18 = 20 =$ *thickness of ring added to inner diameter.*

$20 \times 2 \times 9.8696 =$ *sum above obtained* $\times$ *thickness of ring, and that product by* $9.8696 = 394.784$ *ins.*

Link.

Definition.—An elongated ring.

To Compute Surface of a Link.—Figs. 45 and 46.

Rule.—Multiply length of axis of link by circumference of a section of ody, *a b*.

Or, $l \times c =$ *surface.*

To Compute Length of Axis and Circumference.

When Ring is Elongated. **Rule.**—To less diameter add the diameter of he body of the link, and multiply sum by 3.1416; subtract less diameter rom greater, multiply remainder by 2, and sum of these products is length of axis.

'ig. 45.

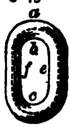
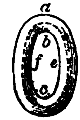


Fig. 46.



Example.—Link of a chain, Fig. 45, is 1 inch in diameter of body, *a b*, and its inner diameters, *b c* and *e f*, are 12.5 and 2.5 inches; what is its circumference?

$2.5 + 1 \times 3.1416 = 10.9956 =$ *length of axis of ends.*

$12.5 - 2.5 \times 2 = 20 =$ *length of sides of body.*

Then $10.9956 + 20 = 30.9956 =$ *length of axis of link*, and 30.9956×3.1416 (cir. of 1 inch) $= 97.3758$ *square ins.*

When Ring is Elliptical, Fig. 46. **Rule.**—Square diameters of axes of ing, multiply square root of half their sum by 3.1416, and product is length f axis.

Cones.

Definition.—A figure described by revolution of a right-angled triangle abou' ıe of its legs.

For Sections of a Cone, see Conic Sections, page 379.

To Compute Surface of a Cone.—Fig. 47.

Rule.—Multiply perimeter or circumference of base by slant height, oı ıe of cone; divide product by 2, and add the quotient to area of the base.

Or, $c \times h \div 2 + a' =$ *surface, c representin*[illegible]

‹. 47.

Example.—Diameter, *a b*, Fig. 47, of bas[illegible] and slant height, *a c*, 15; what is surface [illegible]

Circum. of 3 feet $= 9.4248$, and $\frac{9.4248}{2}$[illegible]

[illegible] *face of side; area of base* $3 = 7.068$, and 7[illegible] *square feet.*

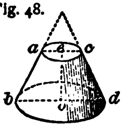
To Compute Surface of the Frustum of a Cone.—Fig. 48.

RULE.—Multiply sum of perimeters of two ends by slant height of frustum; divide product by 2, and add it to areas of two ends.

$$\text{Or, } \frac{c+c' \times h}{2} + a + a' = surface.$$

EXAMPLE.—Frustum, $a\ b\ c\ d$, Fig. 48, has a slant height, $c\ d$, of 26 inches, and circumferences of its ends are 15.71 and 22 inches respectively; what is its surface?

Fig. 48.



$\frac{15.71 + 22 \times 26}{2} = 490.23 = surface\ of\ sides;$ $\left(\frac{15.71}{3.1416}\right)^2 \times .7854 + \left(\frac{22}{3.1416}\right)^2 \times .7854 = 58.119 = areas\ of\ ends.$ Then $490.23 + 58.119 = 548.349$ *square ins.*

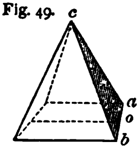
Pyramids.

DEFINITION.—A figure, base of which has three or more sides, and sides of which are plane triangles.

To Compute Surface of a Pyramid.—Figs. 49 and 50.

RULE.—Multiply perimeter of base by slant height; divide product by 2, and add it to area of base.

Fig. 49.



$$\text{Or, } \frac{c\,h}{2} + a = surface.$$

Fig. 50.

EXAMPLE.—Side of a quadrangular pyramid, $a\ b$, Fig. 49, is 12 inches, and its slant height, $o\ c$, 40; what is its surface?

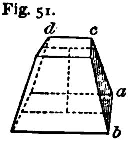
$12 \times 4 = 48 = perimeter\ of\ base.$ $\frac{48 \times 40}{2} = 960 =$ *area of sides*, and $12 \times 12 + 960 = 1104$ *square ins.*

To Compute Surface of Frustum of a Pyramid.—Fig. 51.

RULE.—Multiply sum of perimeters of two ends by slant height; divide product by 2, and add it to areas of ends.

$$\text{Or, } \frac{c+c' \times h}{2} + a + a' = surface.$$

Fig. 51.



EXAMPLE.—Sides $a\ b$, $c\ d$, Fig. 51, of frustum of a quadrangular pyramid are 10 and 9 inches, and its slant height is 20; what is its surface?

$10 \times 4 = 40$, and $9 \times 4 = 36$; $40 + 36 = 76 = sum\ of\ perimeters.$

$76 \times 20 = 1520$, and $\frac{1520}{2} = 760 = area\ of\ sides;$ $10 \times 10 = 100$, and $9 \times 9 = 81$. Then $100 + 81 + 760 = 941 =$ *square ins.*

When Pyramid is Irregular sided or Oblique. RULE.—The surfaces of each of the sides and ends must be computed and added together.

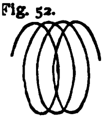
Helix (Screw).

[DEF]INITION.—A line generated by progressive rotation of a point around an axis [eq]uidistant from its centre.

[To Compu]te Length of a Helix.—Fig. 52.

[...] circumference described by generating point, add [...] revolution, extract square root of their [...]olutions of generating point.

Fig. 52.



Or, $\sqrt{(p^2+l^2)}\,n =$ *length*, *n representing number of revolutions.*

EXAMPLE.—What is length of a helical line, Fig. 52, running 3.5 times around a cylinder of 22 inches in circumference, and advancing 16 inches in each revolution?

$22^2 + 16^2 = 740 =$ *sum of squares of circumference and of distance advanced.** Then $\sqrt{740} \times 3.5 = 95.21$ *ins.*

To Compute Length of a Revolution of Thread of a Screw.

RULE.—Proceed as above for length and omit number of revolutions.

Spirals.

DEFINITION.—Lines generated by the progressive rotation of a point around a fixed axis.

A *Plane Spiral* is when the point rotates around a central point.

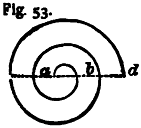
A *Conical Spiral* is when the point rotates around an axis at a progressing distance from its centre, as around a cone.

To Compute Length of a Plane Spiral Line.—Fig. 53.

RULE.—Add together greater and less diameters; divide their sum by 2; multiply quotient by 3.1416, and again by number of revolutions.

Or, when circumferences are given, take their mean length, and multiply it by number of revolutions.

Fig. 53.



Or, $d + d' \div 2 \times 3.1416\, n =$ *length of line;* $P \times n =$ *radius,* and $p\, r^2 \div l =$ *pitch.* P *representing the pitch.*

EXAMPLE.—Less and greater diameters of a plane spiral spring, as *a b*, *c d*, Fig. 53, are 2 and 20 inches, and number of revolutions 10; what is length of it?

$\overline{2+20} \div 2 = 11 =$ *sum of diameters* $\div 2$; $11 \times 3.1416 = 34.5576$.

Then $34.5576 \times 10 = 345.576$ *inches.*

NOTE.—Above rule is applicable to winding engines, see page 862, where it is required to ascertain length of a rope, its thickness, number of revolutions, diameter of drum, etc.

To Compute Length of a Conical Spiral Line.—Fig. 54.

RULE.—Add together greater and less diameters; divide their sum by 2 and multiply quotient by 3.1416.

To square of product of this circumference and number of revolutions of spiral, add square of height of its axis, and take square root of the sum.

Fig. 54.

Or, $\sqrt{(\overline{d + d' \div 2 \times 3.1416\, n}^2 + h^2)} =$ *length of line.*

EXAMPLE.—Greater and less diameters of a conical spiral, Fig. 54, are 20 and 2 inches; its height, *c d*, 10; and number of revolutions 10; what is length of it?

$20 + 2 \div 2 = 11 \times 3.1416 = 34.5576 =$ *sum of diameters* $\div 2$, and $\times$ 3.1416; $34.5576 \times 10 = 345.576$.

Then $\sqrt{345.576^2 + 10^2} = 345.72$ *inches.*

Spindles.

DEFINITION.—Figures generated by revolution of a plane area, revolved about a chord perpendicular to its axis, or about its dou... ...y are designated by the name of the arc or curve from which th... Circular, Elliptic, Parabolic, etc.

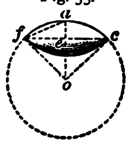
* ...a spiral is other than a line, measure diameters of it from middle of

Circular Spindle.

To Compute Convex Surface of a Circular Spindle, Zone or Segment of it.—Figs. 55, 56, and 57.

Rule.—Multiply length by radius of revolving arc; multiply this arc b central distance, or distance between centre of spindle and centre of revolv ing arc; subtract this product from former, double remain der, and multiply it by 3.1416.

Fig. 55.



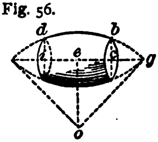
Or, $l\,r - \left(a\sqrt{r^2 - \left(\frac{c}{2}\right)^2}\right) 2\,p =$ *surface, a representing lengt of arc, and c the spindle chord.*

Example.—What is surface of a circular spindle, Fig. 55, lengt of it, $f\,c$, being 14.142 inches, radius of its arc, $o\,c$, 10, and centra distance, $o\,e$, 7.071?

$14.142 \times 10 = 141.42 =$ *length × radius. Length of arc, f a c*, by Rules, page 34 $= 15.708$.

$15.708 \times 7.071 = 111.0713 =$ *length of arc × central distance;* $141.42 - 111.0713 = 30.3487 =$ *difference of products.* Then $30.3487 \times 2 \times 3.1416 = 190.687$ *square ins.*

Fig. 56.



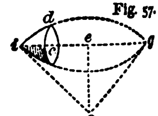
Zone.

Example.—What is convex surface of zone of a circular spindle, Fig. 56, length of it, $i\,c$, being 7.653 inches, radius of its arc, $o\,g$, 10, central distance, $o\,e$, 7.071, and length of its side or arc, $d\,b$, 7.854 inches?

$7.653 \times 10 = 76.53 =$ *length × radius;* $7.854 \times 7.071 = 55.5356 =$ *length of arc × central distance;* $76.53 - 55.5356 = 20.9944 =$ *difference of products.*

Then $20.9944 \times 2 \times 3.1416 = 131.912$ *square ins.*

Fig. 57.



Segment.

Example.—What is convex surface of a segment of a circular spindle, Fig. 57, length of it, $i\,c$, being 3.2495 inches, radius of its arc, $o\,g$, 10, central distance, $o\,e$, 7.071, and length of its side, $i\,d$, 3.927 inches?

$3.2495 \times 10 = 32.495 =$ *length × radius;* $3.927 \times 7.071 = 27.7678 =$ *length of arc × central distance;* $32.495 - 27.7678 = 4.7272 =$ *difference of products.*

Then $4.7272 \times 2 \times 3.1416 = 29.702$ *square ins.*

General Formula.—$S = 2\,(l\,r - a\,c)\,p =$ *surface, l representing length of spindle, segment, or zone, a length of its revolving arc, r radius of generating circle, and c central distance.*

Illustration.—Length of a circular spindle is 14.142 inches, length of its revolving arc is 15.708, radius of its generating circle is 10, and distance of its centre from centre of the circle from which it is generated is 7.071; what is its surface?

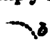
$$2 \times (14.142 \times 10 - \overline{15.708 \times 7.071}) \times 3.1416 = 190.687 \textit{ square inches.}$$

Note.—Surface of a frustum of a spindle may be obtained by division of the surface of a zone.

Cycloidal Spindle.

Compute Convex Surface of a Cycloidal Spindle.—Fig. 58.

—Multiply area of generating circle by 64, and divide it by 3.



Or, $\frac{a \times 64}{3} =$ *surface.*

Example.—Area of generating circle, $a\,b\,c$, of a cycloida $d\,e$, is 32 inches; what is surface of spindle?

—8 = *area of circle* × 64, and 2048 ÷ 3 =

cycloidal spindle is twice area o

Ellipsoid, Paraboloid, or Hyperboloid of Revolution.

DEFINITION.—Figures alike to a cone, generated by revolution of a conic section round its axis.

NOTE.—These figures are usually known as Conoids.

When they are generated by revolution of an ellipse, they are termed Ellipsoids; and when by a parabola, Paraboloids, etc.

Revolution of an arc of a conic section around the axis of the curve will give a segment of a conoid.

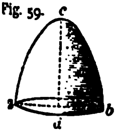
Ellipsoid.

To Compute Convex Surface of an Ellipsoid.—Fig. 59.

RULE.—Add together square of base and four times square of height; multiply square root of half their sum by 3.1416, and this product by radius of the base.

Or, $\sqrt{\frac{b^2+4h^2}{2}}\; 3.1416\, r =$ surface.

Fig. 59.



EXAMPLE.—Base, $a\,b$, of an ellipsoid, Fig. 59, is 10 inches, and vertical height, $c\,d$, 7; what is its surface?

$10^2 + 7^2 \times 4 = 296 =$ *sum of square of base and 4 times square of height*; $296 \div 2 = 148$, and $\sqrt{148} = 12.1655$ = *square root of half above sum.* Then $12.1655 \times 3.1416 \times \frac{10}{2} = 191.09$ square ins.

To Compute Convex Surface of a Segment, Frustum, or Zone of an Ellipsoid.—Fig. 59.

See Rules for Convex Surface of a Segment, Frustum, or Zone of a Spheroid or Ellipsoid, pages 348–9.

$$d \text{ or } d' \times 3.1416 \times h = \textit{surface},$$

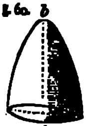
and $\frac{\textit{mean. diam.} \times h}{d \text{ or } d'} = h$; then $d \times 3.1416 \times h =$ *surface.*

Paraboloid.

To Compute Convex Surface of a Paraboloid.—Fig. 60.

RULE.—From cube of square root of sum of four times square of height and square of radius of base, subtract cube of radius of base; multiply remainder by quotient of 3.1416 times radius of base divided by six times square of height.

Fig. 60.



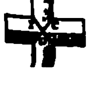
Or, $(\sqrt{4h^2 + r^2})^3 - r^3 \times \frac{\pi r}{6 h^2} =$ surface.

EXAMPLE.—Axis, $b\,d$, of a paraboloid, Fig. 60, is 40 inches, and radius, $a\,d$, of its base is 18 inches; what is its convex surface?

$40^2 \times 4 = 6400 = 4$ *times square of height*; $6400 + 18^2 = 6724 =$ *sum of above product and square of radius of base*; $\sqrt{6724}^3 - 18^3 =$ *545536 = remainder of cube of radius of base from cube of square root of preceding sum*; $3.1416 \times 18 \div 6 \times 1600 = .0058905 =$ *quotient of 3.1416 times radius of base* $\div$ *6 times square of height.*

Then $545536 \times .0058905 = 3213.48$ square ins.

Fig. 61.



Cylinder Sections.

To Compute Surface of a Cylinder Section.—Fig. 61.

RULE.—From entire surface of cylinder subtract surface of the two ungulas, *r e, o* [illegible], and multiply result by 4.

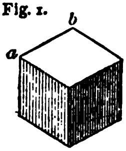
MENSURATION OF VOLUMES.

Cubes and Parallelopipedons.

Cube.

DEFINITION.—A volume contained by six equal square sides.

Fig. 1.



To Compute Volume of a Cube.—Fi

RULE.—Multiply a side of cube by itself, and that p again by a side.

Or, $s^3 = V$, *s representing length of a side, and* V *volu*

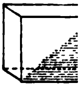
EXAMPLE.—Side, *a b*, Fig. 1, is 12 inches; what is volum

$12 \times 12 \times 12 = 1728$ *cube ins.*

Parallelopipedon.

DEFINITION.—A volume contained by six quadrilateral sides, every oppos of which are equal and parallel.

To Compute Volume of a Parallelopipedon. —Fig. 2.



RULE.—Multiply length by breadth, and that product again by depth.

Or, $l\,b\,d = V$.

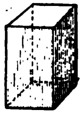
Prisms, Prismoids, and Wedges.

Prisms.

DEFINITION.—Volumes, ends of which are equal, similar, and parallel plan sides of which are parallelograms.

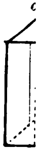
NOTE.—When ends of a prism or prismoid are triangles, it is termed a *tria prism* or *prismoid;* when rhomboids, a *rhomboidal prism*, and when squ *square prism*, etc.

Fig. 3.



To Compute Volume of a Prism.—Figs. 3 and 4.

F



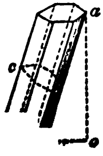
RULE.—Multiply area of base by height.

Or, $a\,h = V$.

EXAMPLE.—A triangular prism, *a b c*, Fig. 4, has sides of 2.5 feet, and a length, *c b*, of 10; what is its volume?

By Rule, page 339, $2.5^2 \times .433 = 2.70625$ = *area of end a b*, and $2.70625 \times 10 = 27.0625$ *cube feet.*

Fig. 5.



When a Prism is Oblique or Irregular.

RULE.—Multiply area of an end by height, as *a* multiply area taken at a right angle to sides, as at actual length.

To Compute Volume of any Frustum Prism, whether Right or Oblique.—] 6 and 7.

RULE.—Multiply area of base by perpend distances between it and centre of gravity of or other end.

EXAMPLE.—Area of base, *a o*, of frustum of a r cylindrical prism, Fig. 6, is 15 inche to centre of gravity, *c*, is 12; what is i

2 = 120 cube ins.

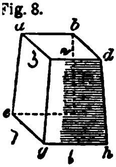
Prismoids.*

To Compute Volume of a Prismoid.—Fig. 8.

Rule.—To sum of areas of the two ends add four times area of middle section, parallel to them, and multiply this sum by one sixth of perpendicular height.

Note.—This is the general rule, and known as the *Prismoidal Formula*, and it applies equally to all figures of proportionate or dissimilar ends.

Fig. 8.



Or, $a + a' + \overline{4\,m \times h} \div 6 = V$, *a and a′ representing areas of ends, and m area of middle section.*

Example.—What is volume of a rectangular prismoid, Fig. 8, lengths and breadths, $e\,g$ and $g\,h$, $a\,b$ and $b\,d$, of two ends being 7×6 and 3×2 inches, and height 15 feet?

$7 \times 6 + \overline{3 \times 2} = 42 + 6 = 48 =$ *sum of areas of two ends*; $7 + 3 \div 2 = 5 =$ *length of middle section*; $6 + 2 \div 2 = 4 =$ *breadth of middle section*; $5 \times 4 \times 4 = 80 =$ *four times area of middle section.*

Then $48 + 80 \times \frac{15 \times 12}{6} = 128 \times 30 = 3840$ *cube ins.*

Note 1.—Length and breadth of middle section are respectively equal to half sum of lengths and breadths of the two ends.

2.—Prismoids, alike to prisms, derive their designation from figure of their ends, as triangular, square, rectangular, pentagonal, etc.

When it is Irregular or Oblique and their ends are united by plane or curved surfaces, through which and every point of them, a right line may be drawn from one of the ends or parallel faces to the other.—Figs. 9, 10, and 11.

Fig. 9.

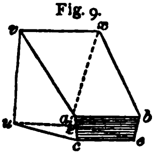


Fig. 10.

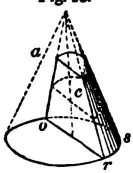
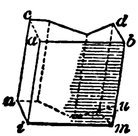


Fig. 11.



Example.—Areas of ends, $a\,c$ and $o\,r\,s$, Fig. 10, $a\,b\,c\,d$, and $i\,m\,n\,u$, Fig. 11, and $a\,b\,c\,e$ and $v\,x\,w\,z$, Fig. 9, are each 10 and 30 inches, that of their middle section 20, and their perpendicular heights 18; what is their volume?

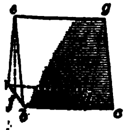
$10 + 30 + \overline{20 \times 4} = 120 =$ *sum of areas of ends + 4 times middle section.* And $120 \times \frac{18}{6} = 360$ *cube ins.*

Wedge.

To Compute Volume of a Wedge.—Fig. 12.

Rule.—To length of edge add twice length of back; multiply this sum by perpendicular height, and then by breadth of back, and take one sixth of product.

Fig. 12.



Or, $(l + \overline{l' \times 2} \times h\,b) \div 6 = V.$

Example.—Length of edge of a wedge, $e\,g$, is 20 inches, back $a\,b\,c\,d$, is 20 by 2, and its height, $e\,f$, 20; what is its volume?

$20 + \overline{20 \times 2} = 60 =$ *length of edge added to twice length of back*; $60 \times 20 \times 2 = 2400 =$ *above sum multiplied by height and that product by breadth of back.*

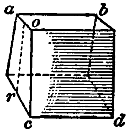
Then $2400 \div 6 = 400$ *cube ins.*

Note.—When a wedge is a true prism, as in Fig. 12, volume of it is equal to area of an end multiplied by its length.

* *Cutting or embankment of a road, when terminated by parallel cross sections.*

To Compute Frustum of a Wedge.—Fig. 13.

Fig. 13.



RULE.—To sum of areas of both ends, add 4 times area of section parallel to and equally distant from both ends, and multiply sum by one sixth of length.

$$\text{Or, } A + a + 4a' \times \frac{l}{6} = V.$$

EXAMPLE.—Lengths of edge and back of a frustum of a wedge *a b* and *c d* are 20 × 1 and 20 × 2 ins., and height *o r* is 20 ins.; what is its volume?

$$\frac{20 \times \overline{2+1}}{2} \times 2 + 4 \times \left(20 \times \frac{2+1}{2}\right) \times \frac{20}{6} = 60 + 120 \times \frac{20}{6} = 600 \textit{ cube ins.}$$

NOTE.—When frustum is a true prism, as represented Fig. 13, volume of it is equal to mean area of ends multiplied by its length.

Regular Bodies (Polyhedrons).

DEFINITION.—A regular body is a solid contained under a certain number of similar and equal plane faces,* all of which are equal regular polygons.

NOTE 1.—Whole number of regular bodies which can possibly be formed is five.

2.—A sphere may always be inscribed within, and may always be circumscribed about a regular body or polyhedron, which will have a common centre.

Fig. 14.

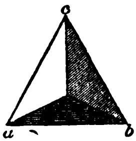


Fig. 15.

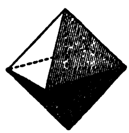


Fig. 16.

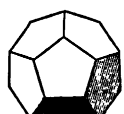
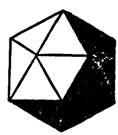


Fig. 17.



1. Tetrahedron, or Pyramid, Fig. 14, which has four triangular faces.
2. Hexahedron, or Cube, Fig. 1, which has six square faces.
3. Octahedron, Fig. 15, which has eight triangular faces.
4. Dodecahedron, Fig. 16, which has twelve pentagonal faces.
5. Icosahedron, Fig. 17, which has twenty triangular faces.

To Compute Elements of any Regular Body.—Figs. 14, 15, 16, and 17.

To Compute Radius of a Sphere that will Circumscribe a given Regular Body, or that may be Inscribed within it.

When Linear Edge is given. RULE.—Multiply it by multiplier opposite to body in columns A and B in following Table, under head of element required.

EXAMPLE.—Linear edge of a hexahedron or cube, Fig. 1, is 2 inches; what are of circumscribing and inscribed spheres?

·866 × 2 = 1.732 04 *inches = radius of circumscribing sphere;* 2 × .5 = 1 *inch =* *f inscribed sphere.*

Surface is given. RULE.—Multiply square root of it by multiplier o body in columns C and D in following Table, under head of uired.

RULE.—Multiply cube root of it by multiplier E and F in following Table, under head of ele-

is termed diedral angle.

en one of the Radii of Circumscribing or Inscribed Sphere alone is re-!, the other being given. RULE.—Multiply given radius by multiplier ite to body in columns G and H in Table, page 364, under head of radius.

To Compute Linear Edge.

en Radius of Circumscribing or Inscribed Sphere is given. RULE.—ply radius given by multiplier opposite to body in columns I and K in page 364.

en Surface is given. RULE.—Multiply square root of it by multiplier te to body in column L in Table, page 364.

en Volume is given. RULE.—Multiply cube root of it by multiplier te to body in column M in Table, page 364.

To Compute Surface.

en Radius of Circumscribing Sphere is given. RULE.—Multiply square ius by multiplier opposite to body in column N in Table, page 364.

en Radius of Inscribed Sphere is given. RULE.—Multiply square of by multiplier opposite to body in column O in Table, page 364.

en Linear Edge is given. RULE.—Multiply square of edge by multi-pposite to body in column P in Table, page 364.

en Volume is given. RULE.—Extract cube root of volume, and multi-uare of root by multiplier opposite to body in column Q in Table, 64.

To Compute Volume.

en Linear Edge is given. RULE.—Cube linear edge, and multiply it ltiplier opposite to body in column R in Table, page 364.

en Radius of Circumscribing Sphere is given. RULE.—Multiply cube lius given by multiplier opposite to body in column S in Table, 64.

en Radius of Inscribed Sphere is given. RULE.—Multiply cube of given by multiplier opposite to body in column T in Table, page 364.

en Surface is given. RULE.—Cube surface given, extract square root, ultiply the root by multiplier opposite to body in column U in Table, 64.

Cylinder.

To Compute Volume of a Solid Cylinder.—Fig. 18.

RULE.—Multiply area of base by height.

EXAMPLE.—Diameter of a cylinder, *b c*, is 3 feet, and its length, *a b*, 7 feet; what is its volume?

Area of 3 feet $= 7.068$. Then $7.068 \times 7 = 49.476$ *cube feet.*

To Compute Volume of a Hollow Cylinder.

E.—Subtract volume of internal cylinder from that of cylinder.

Cone.

To Compute Volume o[illegible] e.—Fig. 19

RULE.—Multiply area of ba[illegible] height, *and take one third of product*

EXAMPLE.—Diameter, *a b*, of b[illegible] height, *c e*, 32.5 inches; what is [illegible]

[illegible] of 15 inches $= 176.7146$. Then $\frac{176.715 \times 3[illegible]}{3}$

Units for Elements of the Regular Bodies.

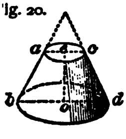
	A. Radius of Circumscribing Sphere. By Linear Edge.	B. Radius of Inscribed Sphere. By Linear Edge.	C. Radius of Circumscribing Sphere. By Surface.	D. Radius of Inscribed Sphere. By Surface.	E. Radius of Circumscribing Sphere. By Volume.	F. Radius of Inscribed Sphere. By Volume.	G. Radius of Inscribed Sphere. By Circumscribing Sphere.	H. Radius of Circumscribing Sphere. By Inscribed Sphere.	I. Linear Edge. By Radius of Circumscribing Sphere.	K. Linear Edge. By Radius of Inscribed Sphere.
..edron....	.612 37	.204 12	.465 3	.155 1	1.248 96	.416 34	.333 33	3	1.632 99	4.898 98
..hedron ...	.866 02	.5	.353 55	.204 12	.866 02	.5	.577 35	1.732 05	1.154 7	2
..edron	.707 11	.408 25	.379 92	.219 35	.908 06	.524 56	.577 35	1.732 05	1.414 21	2.449 49
Dodecahedron ..	1.401 26	1.113 52	.308 39	.245 07	.710 75	.564 8	.794 65	1.258 41	.713 64	.898 06
Icosahedron	.951 06	.755 76	.323 18	.256 81	.733 29	.582 71	.794 65	1.258 41	1.051 46	1.323 17

	Figure.	L. Linear Edge. By Surface.	M. Linear Edge. By Volume.	N. Surface. By Radius of Circumscribing Sphere.	O. Surface. By Radius of Inscribed Sphere.	P. Surface. By Linear Edge.	Q. Surface. By Volume.	R. Volume. By Linear Edge.	S. Volume. By Radius of Circumscribing Sphere.	T. Volume. By Radius of Inscribed Sphere.	U. Volume. By Surface.
4	Tetrahedron ...	.759 84	2.039 55	4.618 8	41.569 22	1.732 05	7.205 62	.117 85	.513 2	13.856 41	.051 7
6	Hexahedron ...	.408 25	1	8	24	6	6	1	1.539 6	8	.068 04

To Compute Volume of Frustum of a Cone.—Fig. 20.

RULE.—Add together squares of the diameters or circumferences of greater and lesser ends and product of the two diameters or circumferences; multiply their sum respectively by .7854 or .079 58, and this product by height; then divide this last product by 3.

Fig. 20.



Or, $d^2+d'^2+\overline{d\times d'}\times .7854\,h\div 3=\text{V}$.

Or, $c^2+c'^2+\overline{c\times c'}\times .079\,58\,h\div 3=\text{V}$.

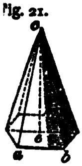
EXAMPLE.—What is volume of frustum of a cone, diameters of greater and lesser ends, *b d*, *a c*, being 5 and 3 feet, and height, *e o*, 9?

$5^2+3^2+\overline{5\times 3}=49$; and $49\times .7854=38.4846=$ *above sum by* .7854; and $\frac{38.4846\times 9}{3}=115.4538$ *cube feet.*

Pyramid.

NOTE.—Volume of a pyramid is equal to one third of that of a prism having equal bases and altitude.

Fig. 21.



To Compute Volume of a Pyramid.—Fig. 21.

RULE.—Multiply area of base by perpendicular height, and take one third of product.

EXAMPLE.—What is the volume of a hexagonal pyramid, Fig. 21, a side, *a b*, being 40 feet, and its height, *e c*, 60?

$40^2\times 2.5981$ (tabular multiplier, page 339) $=4156.96=$ *area of base.*

$\frac{4156\,96\times 60}{3}=83\,139.2$ *cube feet.*

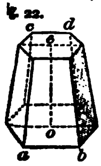
To Compute Volume of Frustum of a Pyramid.—Fig. 22.

RULE.—Add together squares of sides of greater and lesser ends, and product of these two sides; multiply sum by tabular multiplier for areas in table, page 339, and this product by height; then divide last product by 3.

Or, $s^2+s'^2+\overline{s\times s'}\times$ *tab. mult.* $\times h\div 3=\text{V}$.

When Areas of Ends are known, or can be obtained without reference to tabular multiplier, use following.

Fig. 22.



Or, $a+a'+\sqrt{a\times a'}\times h\div 3=\text{V}$.

EXAMPLE.—What is the volume of the frustum of a hexagonal pyramid, Fig. 22, the lengths of the sides of the greater and lesser ends, *a b*, *c d*, being respectively 3.75 and 2.5 feet, and its perpendicular height, *e o*, 7.5?

$3.75^2+2.5^2=20.3125=$ *sum of squares of sides of greater and lesser ends;* $20.3125+\overline{3.75\times 2.5}=29.6875=$ *above sum added product of the two sides;* $29.6875\times 2.5981\times 7.5=578.48\times$ *t mult., and again by the height,* which, $\div 3=192.83$ *cube feet.*

When Ends of a Pyramid are not those of a Regular Polygon, or wi reas of Ends are given

RULE.—Add together areas of the two ends and square root of their pr t; multiply sum by height, and take one third of pr

Or, $a+a'+\sqrt{a\,a'}\times h\div 3=\text{V}$.

EXAMPLE.—What is the volume of an irregular-sided fr as of the two ends being 22 and 88 inches, and the leng

$22+88=110=$ *sum of areas of ends;* $22\times 88=1936$, *s roduct of areas.* Then $\frac{110+44\times 20}{3}=1026.66$ *cub.*

Spherical Pyramid.

A Spherical Pyramid is that part of a sphere included within three or more adjoining plane surfaces meeting at centre of sphere. The spherical polygon defined by these plane surfaces of pyramid is termed the base, and the lateral faces are sectors of circles.

NOTE.—To compute the Elements of Spherical Pyramids, see Docharty and Hackley's Geometry.

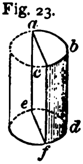
Cylindrical Ungulas.

DEFINITION.—Cylindrical Ungulas are frusta of cylinders. Conical Ungulas are frusta of cones.

To Compute Volume of a Cylindrical Ungula.—Fig. 23.

1. *When Section is parallel to Axis of Cylinder.* RULE.—Multiply area of base by height of the cylinder.

Fig. 23.



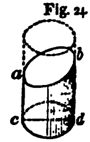
Or, $a\,h = V$.

EXAMPLE.—Area of base, *d e f*, Fig. 23, of a cylindrical ungula is 15.5 inches, and its height, *a e*, 20; what is its volume?

$15.5 \times 20 = 310$ *cube ins.*

2. *When Section passes Obliquely through opposite sides of Cylinder*, Fig. 24. RULE.—Multiply area of base of cylinder by half sum of greatest and least lengths of ungula.

Fig. 24.



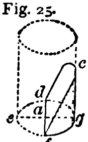
Or, $a \times \overline{l + l'} \div 2 = V$.

EXAMPLE.—Area of base, *c d*, of a cylindrical ungula, Fig. 24, is 25 inches, and the greater and less heights of it, *a c*, *b d*, are 15 and 17; what is its volume?

$$25 \times \frac{15+17}{2} = 400 \text{ cube ins.}$$

3. *When Section passes through Base of Cylinder and one of its Sides, and Versed Sine does not exceed Sine, or the Base is equal to or less than a Semicircle*, Fig. 25. RULE.—From two thirds of cube of sine of half arc of base subtract product of area of base and cosine* of half arc. Multiply difference thus found by quotient arising from height divided by versed sine.

Fig. 25.



Or, $\frac{2\ sin.^3}{3} - \overline{a\,c} \times \frac{h}{v.\ sin.} = V$, *v. sin. representing versed sine.*

EXAMPLE.—Sine, *a d*, of half arc, *d e f*, of base of an ungula, Fig. 25, is 5 inches, diameter of cylinder is 10, and height, *e g*, of ungula 10; what is its volume?

Two thirds of $5^3 = 83.333 =$ *two thirds of cube of sine.* As versed sine and radius of base are equal, cosine is 0. Hence, area of base $\times$ cosine $= 0$, and $83.333 - 0 \times 10 \div 5 = 166.666$ *cube ins.*

4. *When Section passes through Base of Cylinder, and Versed Sine exceeds Radius, or when the Base exceeds a Semicircle*, Fig. 26. RULE.—To two thirds of cube of sine of half arc of base add product of area of base and cosine. Multiply sum thus found by quotient arising from height, divided ...sed sine.

$$\text{Or, } \frac{2\ sin.^3}{3} + \overline{a\,c} \times \frac{h}{v.\ sin.} = V.$$

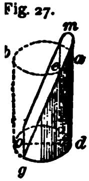
...MPLE.—Sine, *a d*, of half arc of an ungula, Fig. 26, is 12 inches ... sine, *a g*, is 16, height, *g c*, 10, and diameter of cylinder 25 ... its volume?

...s of $12^3 = 1152 =$ *two thirds of cube of sine of half arc of* ... $= 331.78$; $1152 + 331.78 \times 16 - 12.5 = 2313.23 =$ ... *of sine of half the arc of base, and product of* ... $2313.23 \times 20 \div 16 = 2891.5375$ *cube ins.*

5. *When Section passes Obliquely through both Ends of Cylinder*, Fig. 27. RULE.—Conceive section to be continued till it meets side of cylinder produced; then, as the difference of versed sines of the arcs of the two ends of ungula is to the versed sine of arc of less end, so is the height of cylinder to the part of side produced.

Ascertain volume of each of the ungulas by Rules 3 and 4, and take their difference.

Fig. 27.



Or, $\frac{v.\,sin.'\,h}{v.\,sin. - v.\,sin.'} = h'$, *v. sin. and v. sin.' representing versed sines of arcs of the two ends, h height of cylinder, and h' height of part produced.*

EXAMPLE.—Versed sines, *a e*, *d o*, and sines, *e* and *o*, of arcs of two ends of an ungula, Fig. 27, are assumed to be respectively 8.5 and 25, and 11.5 and 0 inches, length of ungula, *b o*, within cylinder, cut from one having 25 inches diameter, *d o*, is 20 inches; what is height of ungula produced beyond cylinder, and what is volume of it?

$25 \sim 8.5 : 8.5 :: 20 : 10.303 =$ *height of ungula produced beyond cylinder.*

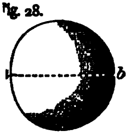
Greater ungula, sine *o* being 0, versed sine = *the diameter.* Base of ungula being a circle of 25 inches diameter, area = 490.875. Versed sine and diameter of base being equal (25), sine = 0. $490.875 \times 25 \sim \frac{25}{2} = 6135.9375 =$ *product of area of base and cosine, or excess of versed sine over sine of base.* $30.303 \div 25 = 1.212\,12 =$ *quotient of height ÷ versed sine.*

Then $6135.9375 \times 1.212\,12 = 7437.4926$ *cube inches;* and by Rules 3 and 4, volumes of less and greater ungulas = 515.444, and 6922.0486 = 7437.4926 *cube inches.*

Sphere.

DEFINITION.—A solid, surface of which is at a uniform distance from the centre.

Fig. 28.



To Compute Volume of a Sphere.—Fig. 28.

RULE.—Multiply cube of diameter by .5236.

Or, $d^3 \times .5236 = V$, *d representing diameter.*

EXAMPLE.—What is volume of a sphere, Fig. 28, its diameter, *a b*, being 10 inches?

$10^3 = 1000$, and $1000 \times .5236 = 523.6$ *cube ins.*

To Compute Volume of a Hollow Sphere.

RULE.—Subtract volume of internal space from that of sphere.

Or, $V - v =$ *volume.*

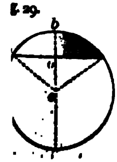
Segment of a Sphere.

DEFINITION.—A section of a sphere.

To Compute Volume of a Segment of a Sphere.—Fig. 2[illegible]

RULE 1.—To three times square of radius of its base add square of height; multiply this sum by height, and product by .5236.

Fig. 29.



Or, $\overline{3\,r^2 + h^2}\,h \times .5236 = V.$

2.—From three times diameter of sphere subtract tw[illegible] height of segment; multiply this remai[illegible] height, and product by .5236.

Or, $\overline{3\,d - 2\,h}\,h^2 \times .5236 =$

EXAMPLE.—Segment of a sphere, Fig. 29, [illegible] inches for its base, and a height, *b o*, of 4;

$7^2 \times 3 + 4^2 = 163 =$ *the sum of three time[illegible]* height; $163 \times 4 \times .5236 = 331.3872$ *cube ins.*

Spherical Zone (or Frustum of a Sphere).

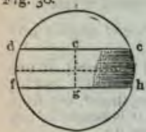
Definition.—Part of a sphere included between two parallel chords.

To Compute Volume of a Spherical Zone.—Fig. 30.

Definition.—Part of a sphere included between two parallel planes.

Rule.—To sum of squares of the radii of the two ends add one third of square of height of zone; multiply this sum by height, and again by 1.5708.

Fig. 30.



Or, $r^2 + r'^2 + \overline{h^2 \div 3}\, h \times 1.5708 = V$.

Example.—What is the volume of a spherical zone, Fig. 30, greater and less diameters, $f\,h$ and $d\,e$, being 20 and 15 inches, and distance between them, or height of zone, $c\,g$, being 10 ins.?

$10^2 + \underline{7.5^2} = 156.25$ = *sum of squares of radii of the two ends.*

$156.25 + 10^2 \div 3 = 189.58$ = *above sum added to one third of square of the height.*

Then $189.58 \times 10 \times 1.5708 = 2977.9226$ *cube ins.*

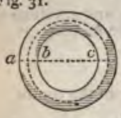
Cylindrical Ring.

Definition.—A ring formed by the curvature of a cylinder.

To Compute Volume of a Cylindrical Ring.—Fig. 31.

Rule.—To diameter of body of ring add inner diameter of ring; multiply sum by square of diameter of body, and product by 2.4674.

Fig. 31.



Or, $\overline{d + d'}\, d^2\, 2.4674 = V$.

Or, $a\,l = V$, *a representing area of section of body, and l length of axis of body.*

Example.—What is volume of an anchor ring, Fig. 31, diameter of metal, $a\,b$, being 3 inches, and inner diameter of ring, $b\,c$, 8?

$3 + 8 \times 3^2 = 99$ = *product of sum of diameters and square of diameter of body of ring.*

Then $99 \times 2.4674 = 244.2726$ *cube ins.*

Spheroids (Ellipsoids).

Definition.—Solids generated by the revolution of a semi-ellipse about one of its diameters. When the revolution is about the transverse diameter they are termed Prolate, and when about the conjugate they are Oblate.

To Compute Volume of a Spheroid.—Fig. 32.

Rule.—Multiply square of revolving axis by fixed axis, and this product by .5236.

Fig. 32.

Or, $a^2\, a' \times .5236 = V$, *a and a′ representing revolving and fixed axes.*

Or, $4 \div 3 \times 3.1416\, r^2\, r' = V$, *r and r′ representing semi-axes.*

Example.—In a prolate spheroid, Fig. 32, fixed axis, $a\,b$, is 14 inches, and revolving axis, $c\,d$, 10; what is its volume?

$10^2 \times 14 = 1400$ = *product of square of revolving axis and fixed axis.* Then $1400 \times .5236 = 733.04$ *cube ins.*

Note.—Volume of a spheroid is equal to ⅔ of a cylinder that will circumscribe it.

Segments of Spheroids.

To Compute Volume of Segment of a Spheroid.—Fig. 33.

When Base, e f, is Circular, or parallel to revolving Axis, as c d, Fig. 33, *or as e f to Axis a b,* Fig. 34. Rule.—Multiply fixed axis by 3, height of segment by 2, and subtract one product from the other; multiply remainder by square of height of segment, and product by .5236. Then, as square of fixed axis is to square of revolving axis, so is last product to volume of segment.

$$\text{Or, } \frac{\overline{3\,a - 2\,h}\; h^2 \times .5236 \times a'^2}{a^2} = \text{V.}$$

EXAMPLE.—In a prolate spheroid, Fig. 33, fixed or transverse axis, *a b*, is 100 inches, revolving or conjugate, *c d*, 60, and height of segment, *a o*, 10; what is its volume?

$100 \times \overline{3 - 10 \times 2} = 280 =$ *twice the height of segment subtracted from three times fixed axis;* $280 \times 10^2 \times .5236 =$ = *product of above remainder, square of height, and* .5236. Then 569.8 : 5277.888 *cube ins.*

, *e f, is Elliptical, or perpendicular to revolving Axis, a b,* Fig. *to Axis c d,* Fig. 34. RULE.—Multiply fixed axis by 3, segment by 2, and subtract one from the other; multiply re- juare of height of segment, and product by .5236. Then, as o revolving axis, so is last product to volume of segment.

$$\text{Or, } \frac{\overline{3\,a' - 2\,h}\; h^2 \times .5236 \times a}{a'} = \text{V.}$$

EXAMPLE.—Diameters of an oblate spheroid, Fig. 34, are 100 and 60 inches, and height of a segment thereof is 12; what is its volume?

$100 \times \overline{3 - 12 \times 2} = 276 =$ *twice the height of the segment subtracted from three times the revolving axis;* $276 \times 12^2 \times .5236$: *product of above remainder, the square of height, and* .5236. :: 20 809.9584 : 12 485.975 *cube ins.*

Frusta of Spheroids.

te Volume of Middle Frustum of a Spheroid.— Fig. 35.

, *e f and g h, are Circular, or parallel to revolving Axis, as c d,* b, Fig. 36. RULE.—To twice square of revolving axis add neter of either end; multiply this sum by length of frustum, y .2618.

$$\text{Or, } 2\,a'^2 + d^2 \times l\,.2618 = \text{V.}$$

EXAMPLE.—Middle frustum of a prolate spheroid, *i o*, Fig. 35, is 36 inches in length, diameter of it being, in middle, *c d*, 50, and at its ends, *e f* and *g h*, 40; what is its volume?

$50^2 \times 2 + 40^2 = 6600 =$ *sum of twice square of middle diameter added to square of diameter of ends.* Then $6600 \times 36 \times .2618 = 62\,203.68$ *cube ins.*

, *e f and g h, are Elliptical, or perpendicular to revolving Axis,* · *e f and g h to Axis, c d,* Fig. 36. RULE.—To twice product and conjugate diameters of middle section, add product of d conjugate of either end; multiply this sum by length of product by .2618.

$$\text{Or, } d\,d' \times 2 + \overline{d\,d'}\; l \times .2618 = \text{V.}$$

EXAMPLE.—In middle frustum of a prolate spheroid, Fig. 36, diameters of its middle section are 50 and 30 inches, its ends 40 and 24, and its length, *o i*, 18; what is its volume?

$50 \times 30 \times 2 = 3000 =$ *twice product of transverse and conjugate diameters;* $3000 + \overline{40 \times 24} = 3960 =$ *sum of above product and product of transverse and conjugate diameters of ends.*

$\times .2618 = 18\,661.104$ *cube ins.*

Links.

DEFINITION.—Elongated or Elliptical rings.

Elongated or Elliptical Links.

To Compute Volume of an Elongated or Elliptical Li —Figs. 37 and 38.

RULE.—Multiply area of a section of the body of link by its lengt circumference of its axis.

Or, $a\,l$ or $c = V$.

NOTE.—By Rule, page 353, Circumference or length of axis of an Elongate = the sum of 3.1416 times sum of less diameter added to thickness of rin product of twice remainder of less diameter subtracted from greater.

Also, Circumference or length of axis of an Elliptical ring = square root o sum of diameters added to thickness of ring or axes squared × 3.1416.

Fig. 37.

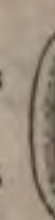
EXAMPLE.—Elongated link of a chain, Fig. 37, is 1 inch in dia of body, $a\,b$, and its inner diameters, $b\,c$ and $e\,f$, are 10 and 2.5 in what is its volume?

Area of 1 inch = .7854; 2.5 + 1 × 3.1416 = 10.9956 = 3.1416 *time of less diameter and thickness of ring = length of axis of ends;* 10 × 2 = 15 = *twice remainder of the less diameter subtracted from g = length of sides of body.*

Then 10.9956 + 15 = 25.9956 = *length of axis of length.*

Hence .7854 × 25.9956 = 20.417 *cube ins.*

Fi



2.—Elliptical link of a chain, Fig. 38, is of the same dimensions as preceding; what is its volume?

$\overline{2.5+1}^2 + \overline{10+1}^2 = 133.25 =$ *diameter of axes squared;* $\sqrt{\frac{133.25}{2}}\ 3.1416$ = 25.643 = *square root of half sum of diameters squared* × 3.1416 = *circumference of axis of ring.* Area of 1 inch = .7854.

Then 25.643 × .7854 = 20.14 *cube ins.*

Spherical Sector.

DEFINITION.—A figure generated by the revolution of a sector of a circle at straight line through the vertex of the sector as an axis.

NOTE.—Arc of sector generates surface of a zone, termed base of sector sphere, and the radii generate surfaces of two cones, having a vertex in co with the sector at the centre of the sphere.

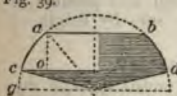
To Compute Volume of a Spherical Sector.—Fig.

RULE.—Multiply external surface of zone, which is base of sector, by third of the radius of sphere.

Or, $a\,\overline{r \div 3} = V$, *a representing area of base.*

NOTE.—Surface of a spherical sector = sum of surface of zone and surfaces o two cones.

Fig. 39.



EXAMPLE.—What is volume of a spherical sector, 39, generated by sector, $c\,a\,h$, height of zone, $a\,b\,c$ ing $a\,o$, 12 inches, and radius, $g\,h$, of sphere 15?

12 × 94.248 = 1130.976 = *height of zone × circumfe of sphere = external surface of zone* (see page 350).

1130 976 × $\overline{15 \div 3}$ = *surface × one third of radi* 5654 88 *cube ins.*

Spindles.

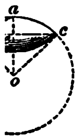
DEFINITION.—Figures generated by revolution of a plane area bounded by a cur when the curve is revolved about a chord perpendicular to its axis or about double ordinate, and they are designated by the name of arc from which they generated, as Circular, Elliptic, Parabolic, etc.

Circular Spindle.

;ompute Volume of a Circular Spindle.—Fig. 40.

E.—Multiply central distance by half area of revolving segment; :t product from one third of cube of half length, and multiply re- :r by 12.5664.

$$\frac{\div 2)^3}{3} - \left(c \times \frac{a}{2}\right) \times 12.5664 = V,$$ *a representing area of revolving segment.*



EXAMPLE.—What is volume of a circular spindle, Fig. 40, when central distance, *o e*, is 7.071 067 inches, length, *f c*, 14.142 13, and radius, *o c*, 10?

NOTE.—Area of revolving segment; *f e*, being = side of square that can be inscribed in a circle of 20, is $\overline{20^2 \times .7854 - 14.142\,13^2 \div 4} = 28.54$ *area.*

$7.071\,067 \times \overline{28.54 \div 2} = 100.9041 =$ *central distance* $\times$ *half area of revolving segment;* $\frac{7.071\,67^3}{3} - 100.9041 = 16.947 =$ *remainder of roduct and one third of cube of half length.*

Then $16.497 \times 12.5664 = 212.9628$ *cube ins.*

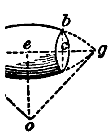
;'rustum or Zone of a Circular Spindle.*

ompute Volume of a Frustum or Zone of a Circular Spindle.—Fig. 41.

E.—From square of half length of whole spindle take one third of of half length of frustum, and multiply remainder by said half length stum; multiply central distance by revolving area which generates stum; subtract this product from former, and multiply remainder by

$$\overline{\div 2}^2 - \frac{\overline{l' \div 2}^2}{3} \times \frac{l'}{2} - (c \times a) \times 6.2832 = V,$$ *l and l' representing lengths of and of frustum, and a area of revolving section of frustum.*

. —Revolving area of frustum can be obtained by dividing its plane into a t of a circle and a parallelogram.



EXAMPLE.—Length of middle frustum of a circular spindle, *i c*, Fig. 41, is 6 inches; length of spindle, *f g*, is 8; central distance, *o e*, is 3; and area of revolving or generating segment is 10; what is volume of frustum?

$(8 \div 2)^2 - \frac{(6 \div 2)^2}{3} = 13$, and $13 \times 3 = 39 =$ *product of* $\frac{1}{2}$ *length of frustum, and remainder of one third square of half length of frustum subtracted from square of half length of ;* $39 - \overline{3 \times 10} = 9 =$ *product of central distance and area of segment subtracted receding product.*

Then $9 \times 6.2832 = 56.5488$ *cube ins.*

Segment of a Circular Spindle.

Compute Volume of a Segment of a Circular Spindle.—Fig. 42.

E.—Subtract length of segment from half length of spindle; double ıder, and ascertain volume of a middle frustum of this length. Sub- esult from volume of whole spindle, and halve remainder.†

$) - c \div 2 = V$, *C and c representing volume of spindle and middle frustum.*

'le frustum of a Circular Spindle is one of the various forms of casks.

ule is applicable to segment of any Spindle or any Conoid, volume of the figure and frustu *obtained.*

Links.

Definition.—Elongated or Elliptical rings.

Elongated or Elliptical Links.

To Compute Volume of an Elongated or Elliptical Link. —Figs. 37 and 38.

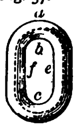
Rule.—Multiply area of a section of the body of link by its length, or circumference of its axis.

Or, $a\,l$ or $c = V$.

Note.—By Rule, page 353, Circumference or length of axis of an Elongated link = the sum of 3.1416 times sum of less diameter added to thickness of ring, and product of twice remainder of less diameter subtracted from greater.

Also, Circumference or length of axis of an Elliptical ring = square root of half sum of diameters added to thickness of ring or axes squared × 3.1416.

Fig. 37.



Example.—Elongated link of a chain, Fig. 37, is 1 inch in diameter of body, $a\,b$, and its inner diameters, $b\,c$ and $e\,f$, are 10 and 2.5 inches; what is its volume?

Area of 1 inch = .7854; $2.5 + 1 \times 3.1416 = 10.9956 = 3.1416$ *times sum of less diameter and thickness of ring = length of axis of ends*; $10 - 2.5 \times 2 = 15 =$ *twice remainder of the less diameter subtracted from greater = length of sides of body.*

Then $10.9956 + 15 = 25.9956 =$ *length of axis of length.*

Hence $.7854 \times 25.9956 = 20.417$ *cube ins.*

Fig. 38.

2.—Elliptical link of a chain, Fig. 38, is of the same dimensions as preceding; what is its volume?

$\overline{2.5+1}^2 + \overline{10+1}^2 = 133.25 =$ *diameter of axes squared*; $\sqrt{\frac{133.25}{2}}\ 3.1416$ $= 25.643 =$ *square root of half sum of diameters squared* $\times\ 3.1416 =$ *circumference of axis of ring.* Area of 1 inch = .7854.

Then $25.643 \times .7854 = 20.14$ *cube ins.*

Spherical Sector.

Definition.—A figure generated by the revolution of a sector of a circle about a straight line through the vertex of the sector as an axis.

Note.—Arc of sector generates surface of a zone, termed base of sector of a sphere, and the radii generate surfaces of two cones, having a vertex in common with the sector at the centre of the sphere.

To Compute Volume of a Spherical Sector.—Fig. 39.

Rule.—Multiply external surface of zone, which is base of sector, by one third of the radius of sphere.

Or, $a\,\overline{r \div 3} = V$, *a representing area of base.*

—Surface of a spherical sector = sum of surface of zone and surfaces of the

Example.—What is volume of a spherical sector, Fig. 39, generated by sector, $c\,a\,h$, height of zone, $a\,b\,c\,d$, being $a\,o$, 12 inches, and radius, $g\,h$, of sphere 15?

$12 \times 94.248 = 1130.976 =$ *height of zone* × *circumference of sphere = external surface of zone* (see page 350).

$1130.976 \times \overline{15 \div 3} =$ *surface* × *one third of radius* = 5654.88 *cube ins.*

Spindles.

... plane area bounded by a curve ... ular to its axis or about ... arc from which they are

Circular Spindle.

npute Volume of a Circular Spindle.—Fig. 40.

·Multiply central distance by half area of revolving segment; roduct from one third of cube of half length, and multiply re- y 12.5664.

$)^3 - \left(c \times \frac{a}{2}\right) \times 12.5664 = V$, *a representing area of revolving segment.*

EXAMPLE.—What is volume of a circular spindle, Fig. 40, when central distance, $o\,e$, is 7.071 067 inches, length, $f\,c$, 14.142 13, and radius, $o\,c$, 10?

NOTE.—Area of revolving segment; $f\,e$, being = side of square that can be inscribed in a circle of 20, is $\overline{20^2 \times .7854 - 14.142\,13^2} \div 4 = 28.54$ *area.*

$7.071\,067 \times \overline{28.54 \div 2} = 100.9041$ = *central distance* × *half area of revolving segment;* $\frac{7.071\,67^3}{3} - 100.9041 = 16.947$ = *remainder of*

ict and one third of cube of half length.

Then $16.497 \times 12.5664 = 212.9628$ *cube ins.*

ıstum or Zone of a Circular Spindle.*

.pute Volume of a Frustum or Zone of a Circular Spindle.—Fig. 41.

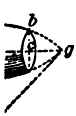
·From square of half length of whole spindle take one third of ıalf length of frustum, and multiply remainder by said half length ı; multiply central distance by revolving area which generates n; subtract this product from former, and multiply remainder by

$- \frac{\overline{l' \div 2}^2}{3} \times \frac{l'}{2} - (c \times a) \times 6.2832 = V$, *l and l′ representing lengths of*

of frustum, and a area of revolving section of frustum.

Revolving area of frustum can be obtained by dividing its plane into a a circle and a parallelogram.

EXAMPLE.—Length of middle frustum of a circular spindle, $i\,c$, Fig. 41, is 6 inches; length of spindle, $f\,g$, is 8; central distance, $o\,e$, is 3; and area of revolving or generating segment is 10; what is volume of frustum?



$(8 \div 2)^2 - \frac{(6 \div 2)^2}{3} = 13$, and $13 \times 3 = 39$ = *product of* $\frac{1}{2}$ *length of frustum, and remainder of one third square of half length of frustum subtracted from square of half length of*

$- \overline{3 \times 10} = 9$ = *product of central distance and area of segment subtract ting product.*

Then $9 \times 6.2832 = 56.5488$ *cube ins.*

Segment of a Circular Spindle.

›mpute Volume of a Segment ...ul Spindle.—Fig. 42.

·Subtract length of segment from half le... and ascertain volume of a middle frustu... t from volume of whole spindle, and halve

$\div 2 = V$, C *and* c *representing volume of spindle*

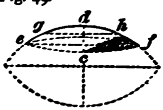
...of a Circular Spindle is one of the various forms of ... applicable to segment of any Spindle or any Conoid, ...

To Compute Volume of a Segment of a Parabolic Spindle.—Fig. 49.

RULE.—Add together square of diameter of base of segment and squar of double diameter in middle between base and vertex; multiply sum b height of segment, and product by .1309.

$$\text{Or, } d^2 + \overline{d''}^2\, l \times .1309 = \text{V}.$$

Fig. 49.



EXAMPLE.—Segment of a parabolic spindle, Fig. 49, ha diameters, *e f* and *g h*, of 15 and 8.75 inches, and height *c d*, is 2.5; what is its volume?

$15^2 + \overline{8.75 \times 2}^2 = 531.25 =$ *sum of square of base and o double diameter in middle of segment.* Then $531.25 \times 2.$ $\times .1309 = 173.852$ *cube ins.*

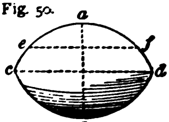
Hyperbolic Spindle.

To Compute Volume of a Hyperbolic Spindle.—Fig. 50.

RULE.—To square of diameter add square of double diameter at one fourth of its length; multiply sum by length, and product by .1309.*

$$\text{Or, } d^2 + \overline{2\, d'}^2\, l \times .1309 = \text{V}.$$

Fig. 50.



EXAMPLE.—Length, *a b*, Fig. 50, of a hyperbolic spindle is 100 inches, and its diameters, *c d* and *e f*, are 150 and 110; what is its volume?

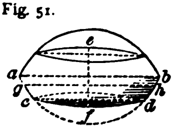
$150^2 + \overline{110 \times 2}^2 \times 100 = 7\,090\,000 =$ *product of sum of squares of greatest diameter and of twice diameter at one fourth of length of spindle and length.* Then $7\,090\,000 \times .1309 = 928\,081$ *cube inches.*

To Compute Volume of Middle Frustum of a Hyperbolic Spindle.—Fig. 51.

RULE.—Add together squares of greatest and least diameters and square of double diameter in middle between the two; multiply this sum by length, and product by .1309.†

$$\text{Or, } d^2 + d'^2 + (2\, d'')^2\, l \times .1309 = \text{V}.$$

Fig. 51.



EXAMPLE.—Diameters, *a b* and *c d*, of middle frustum of hyperbolic spindle, Fig. 51, are 150 and 110 inches; diameter, *g h*, 140; and length, *e f*, 50; what is its volume?

$150^2 + 110^2 + \overline{140 \times 2}^2 = 113\,000 =$ *sum of squares of greatest and least diameters and of double middle diameter.* Then $113\,000 \times 50 \times .1309 = 739\,585$ *cube ins.*

To Compute Volume of a Segment of a Hyperbolic Spindle.—Fig. 52.

RULE.—Add together square of diameter of base of segment and square of ... diameter in middle between base and vertex; multiply sum by ... gment, and product by .1309.

$$\text{Or, } d^2 + d''^2\, l \times .1309 = \text{V}.$$

EXAMPLE.—Segment of a hyperbolic spindle, Fig. 52, has diameters, *e f* and *g h*, of 110 and 65 inches, and its length, *a b*, 25; what is its volume?

... $+ \overline{65 \times 2}^2 = 29\,000 =$ *sum of squares of diameter of base ... uble middle diameter.*

... en $29\,000 \times 25 \times .1309 = 94\,902.5$ *cube ins.*

† Ibid.

llipsoid, Paraboloid, and Hyperboloid of Revolution* (Conoids).

Definition.—Figures like to a cone, described by revolution of a conic section ound and at a right angle to plane of their fixed axes.

Ellipsoid of Revolution (Spheroid).

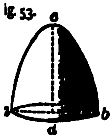
Definition.—An ellipsoid of revolution is a semi-spheroid. (See page 368.)

Paraboloid of Revolution.†

'o Compute Volume of a Paraboloid of Revolution.—Fig. 53.

Rule.—Multiply area of base by half height.

ig. 53.



Or, $a\,h \div 2 = V$.

Note.—This rule will hold for any segment of paraboloid, whether base be perpendicular or oblique to axis of solid.

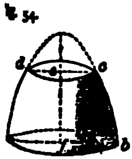
Example.—Diameter, *a b*, of base of a paraboloid of revolution, Fig. 53, is 20 inches, and its height, *d c*, 20; what is its volume?

Area of 20 inches diameter of base $= 314.16$. Then $314.16 \times 20 \div 2 = 3141.6$ *cube ins.*

Frustum of a Paraboloid of Revolution.

To Compute Volume of a Frustum of a Paraboloid of Revolution.—Fig. 54.

ig. 54.



Rule.—Multiply sum of squares of diameters by height of frustum, and this product by .3927.

Or, $(d^2 + d'^2)\,h \times .3927 = V$.

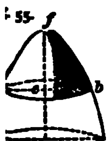
Example.—Diameters, *a b* and *d c*, of the base and vertex of frustum of a paraboloid of revolution, Fig. 54, are 20 and 11.5 inches, and its height, *e f*, 12.6; what is its volume?

$20^2 + 11.5^2 = 532.25 =$ *sum of squares of diameters.* Then $532.25 \times 12.6 \times .3927 = 2633.5837$ *cube ins.*

Segment of a Paraboloid of Revolution.

Compute Volume of Segment of a Paraboloid of Revolution.—Fig. 55.

ig. 55.



Rule.—Multiply area of base by half height.

Or, $a \times \overline{h \div 2} = V$.

Note.—This rule will hold for any segment of paraboloid, whether base be perpendicular or oblique to axis of solid.

Example.—Diameter, *a b*, of the base of a segment of a paraboloid of revolution, Fig. 55, is 11.5 inches, and its height, *e f*, 7.4; what is its volume?

Area of 11.5 inches diameter of base $= 103.869$. Then 103.[illegible] .4 ÷ 2 = 384.315 *cube ins.*

Hyperboloid of Revol[illegible]

Compute Volume of a Hyperbol[illegible] [illegible]tion—Fig. 56.

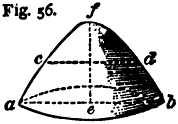
Rule.—To square of radius of base add square o[illegible] y this sum by height, and product by .5236.

---

* [illegible] have been known as Conoids. For the definition [illegible]

† [illegible]aboloid of Revolution is = .5 of its circumference.

Fig. 56.



Or, $r^2 + d^2\ h \times .5236 = V$, *d representing middle diameter*

Example.—Base, $a\ b$, of a hyperboloid of revolution, Fig. 56, is 80 inches; middle diameter, $c\ d$, 66; and height, $e\ f$, 60; what is its volume?

$\overline{80 \div 2}^2 + 66^2 = 5956$ = *sum of square of radius of base and middle diam.* Then $5956 \times 60 \times .5236 = 187\,113.7$ *cube ins.*

Segment of a Hyperboloid of Revolution.

To Compute Volume of Segment of a Hyperboloid of Revolution, as Fig. 56.

Rule.—To square of radius of base add square of middle diameter; multiply this sum by height, and product by .5236.

Or, $r^2 + d''^2\ h \times .5236 = V$, *r representing radius of base.*

Example.—Radius, $a\ e$, of base of a segment of a hyperboloid of revolution, as Fig 56, is 21 inches; its middle diameter, $c\ d$, is 30; and its height, $e\ f$, 15; what is its volume?

$21^2 + 30^2 \times 15 = 20\,115$ = *product of sum of squares of radius of base and middle diameter multiplied by height.* Then $20\,115 \times .5236 = 10\,532.214$ *cube ins.*

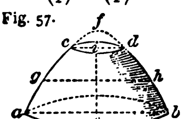
Frustum of a Hyperboloid of Revolution.

To Compute Volume of Frustum of a Hyperboloid of Revolution.—Fig. 57.

Rule.—Add together squares of greatest and least semi-diameters and square of diameter in middle of the two; multiply this sum by height, and product by .5236.

Or, $\left(\frac{d}{2}\right)^2 + \left(\frac{d'}{2}\right)^2 + d''^2\ h \times .5236 = V$, *d, d', and d'' representing several diameters.*

Fig. 57.



Example.—Frustum of a hyperboloid of revolution, Fig. 57, is in height, $e\ i$, 50 inches; diameters of greater and lesser ends, $a\ b$ and $c\ d$, are 110 and 42; and that of middle diameter, $g\ h$, is 80; what is volume?

$110 \div 2 = 55$, and $42 \div 9 = 21$. Hence $55^2 + 21^2 + 80^2 = 9866$ = *sum of squares of semi-diameters of ends and of middle diam.* Then $9866 \times 50 \times .5236 = 258\,291.88$ *cube ins.*

Any Figure of Revolution.

To Compute Volume of any Figure of Revolution.—Fig. 58.

Rule.—Multiply area of generating surface by circumference described by its centre of gravity.

Or, $a\ 2r\ p = V$, *r representing radius of centre of gravity.*

Fig. 58.

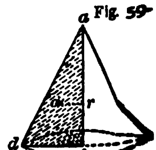
Illustration 1.—If generating surface, $a\ b\ c\ d$, of cylinder, $b\ e\ d\ f$, Fig. 58, is 5 inches in width and 10 in height, then will $a\ b = 5$ and $b\ d = 10$, and centre of gravity will be in o, the radius of which is $r\ o = 5 \div 2 = 2.5$. Hence $10 \times 5 = 50$ = *area of generating surface.*

Then $50 \times 2.5 \times 2 \times 3.1416 = 785.4$ = *area of generating surface × circumference of its ·tre of gravity = volume of cylinder.*

ı cylinder 10 inches in diameter and 10 .7854 = 78.54, and $78.54 \times 10 = 785.4$.

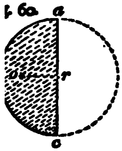
· of a cone, Fig. 59, is $a\ e = 10$, $d\ e =$ ·rea of triangle $= 10 \times 5 \div 2 = 25$, · o, and $o\ r$, by Rule, page 607,

Fig. 59.



·rating surface × circ·

[Fig.] 60.



3.—If generating surface of a sphere, Fig. 60, is $a\,b\,c$, and $a\,c = 10$, $a\,b\,c$ will be $\left(\frac{10^2 \times .7854}{2}\right) = 39.27$, centre of gravity of which is in o, and by Rule, page 607, $o\,r = 2.122$.

Hence, $39.27 \times \overline{2.122 \times 2 \times 3.1416} = 523.6$ = *area of generating surface* × *circumference of its centre of gravity* = *volume of sphere.*

Irregular Bodies.

To Compute Volume of an Irregular Body.

Rule.—Weigh it both in and out of fresh water, and note difference in [lb]s.; then, as 62.5* is to this difference, so is 1728† to number of cube inches [in] body.

Or, divide difference in lbs. by 62.5, and quotient will give volume in [cu]be feet.

Note.—If salt water is to be used, ascertained weight of a cube foot of it, or 64, is [t]o be used for 62.5.

Example.—An irregular-shaped body weighs 15 lbs. in water, and 30 out; what [i]s its volume in cube inches?

$30 - 15 = 15$ = *difference of weights in and out of water.*
$62.5 : 15 :: 1728 : 414.72$ = *volume in cube ins.*
Or, $15 \div 62.5 = .24$, and $.24 \times 1728 = 414.72$ = *volume in cube ins.*

CASK GAUGING.

Varieties of Casks.

To Compute Volume of a Cask.

1st *Variety.* Ordinary form of middle frustum of a Prolate Spheroid.

This class comprises all casks having a spherical outline of staves, as Rum puncheons, Whiskey barrels, etc.

Rule.—To twice square of bung diameter add square of head diameter; [mu]ltiply this sum by length of the cask, and product by .2618, and it will [gi]ve volume in cube inches, which, being divided by 231, will give result in [ga]llons.

2d *Variety.* Middle frustum of a Parabolic Spindle.

This class comprises all casks in which curve of staves quickens at the chime, as Brandy casks and Provision barrels.

Rule.—To square of a head diameter add double square of bung diam[ete]r, and from sum subtract .4 of square of difference of diameters; multiply [rema]inder by length, and product by .2618, which, being divided by 231, [wi]ll give volume in gallons.

3d *Variety.* Middle frustum of a Paraboloid.

This class comprises all casks in which curve of staves quickens slightly a[t] bilge, as Wine casks.

Rule.—To square of bung diameter add square of head diameter; m[ulti]ply sum by length, and product by .3927, which, being divided by 2[31], [wi]ll give volume in gallons.

4th *Variety.* Two equal frustums of Cones.

This class comprises all casks in which curve of staves quickens sharply a[t] bilge, as Gin pipes.

Rule.— ... square of difference of diameters to three ti[mes] ... ply sum by length, and product by .06566 ... inches, which, being divided by 231, wil[l] ...

[* Weight of a cube fo]ot of fresh water. † Number of inch[es] ...

EXAMPLE.—Bung and head diameters of a cask are 24 and 16 inches, and len[g] 36; what is its volume in gallons?

$\overline{24-16}^{2} + \overline{(24+16)^2 \times 3} = 4864$, which $\times\, 36 = 175\,104$, and $175\,104 \times .065\,66$ [=] $11\,497.329$, which $\div\, 231 = 49.77$ *gallons.*

Generally.

$\overline{D\,d + M^2}\ .001\,692\ L =$ *U. S. gallons*, and $.001\,416\,2 =$ *Imperial gallons.*

D, *d*, and M *representing interior, head and bung diameters, and* L *length of c[ask] in inches.*

To Ascertain Mean Diameter of a Cask.

RULE.—Subtract head diameter from bung diameter in inches, and m[ul]tiply difference by following units for the four varieties; add product [to] head diameter, and sum will give mean diameter of varieties required.

1st Variety	.7	3d Variety	.56
2d Variety	.68	4th Variety	.52

EXAMPLE.—Bung and head diameters of a cask of 1st variety are 24 and 20 in[ch]es; what is its mean diameter?

$24 - 20 = 4$, and $4 \times .7 = 2.8$, which, added to 20, $= 22.8$ *ins.*

ULLAGE CASKS.

To Compute Volume of Ullage Casks.

When a cask is only partly filled, it is termed an *ullage cask*, and is c[on]sidered in two positions, viz., as lying on its side, when it is termed a *S[eg]ment Lying*, or as standing on its end, when it is termed a *Segment Standi[ng]*

To Ullage a Lying Cask.

RULE.—Divide wet inches (depth of liquid) by bung diameter; find q[uo]tient in column of versed sines in table of circular segments, page 267, [and] take its corresponding segment; multiply this segment by capacity of c[ask] in gallons, and product by 1.25 for ullage required.

EXAMPLE.—Capacity of a cask is 90 gallons, bung diameter being 32 inches; w[hat] is its volume at 8 inches depth?

$8 \div 32 = .25$, *tab. seg.* of which is $.153\,55$, which $\times\, 90 = 13.8195$, and again $\times\, 1.2[5 =]$ 17.2744 *gallons.*

To Ullage a Standing Cask.

RULE.—Add together square of diameter at surface of liquor, square [of] head diameter, and square of double diameter taken in middle between [the] two; multiply sum by wet inches, and product by .1309, and divide by [231] for result in gallons.

To Compute Volume of a Cask by Four Dimension[s].

RULE.—Add together squares of bung and head diameters, and square [of] double diameter taken in middle between bung and head; multiply the s[um] by length of cask, and product by .1309, and divide this product by 231 [for] result in gallons.

[illegible] pute Volume of any Cask from Three Dime[n]sions only.

[illegible]d into one sum 39 times square of bung diameter, 25 ti[mes] [illegible] diameter, and 26 times product of the two diameters; m[ultiply] [illegible] length [illegible] product by .008 726; and divide quotient by [illegible]

[illegible]

[illegible] and for description and us[e] [illegible] 307-23.

CONIC SECTIONS.

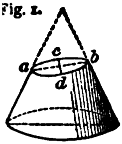
A *Cone* is a figure described by revolution of a right-angled triangle .bout one of its legs, or it is a solid having a circle for its base, and erminated in a vertex.

Conic Sections are figures made by a plane cutting a cone.

If a cone is cut by a plane through vertex and base, section will be a triangle, ınd if cut by a plano parallel to its base, section will be a circle.

Axis is line about which triangle revolves. *Base* is circle which is described by 'evolving base of triangle.

Fig. 1.

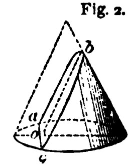


· An *Ellipse* is a figure generated by an oblique plane cutting a cone above its base.

Transverse axis or diameter is longest right line that can be drawn in it, as *a b*, Fig. 1.

Conjugate axis or diameter is a line drawn through centre of ellipse perpendicular to transverse axis, as *c d*.

Fig. 2.

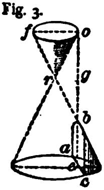


A *Parabola* is a figure generated by a plane cutting a cone parallel to its side, as *a b c*, Fig. 2.

Axis is a right line drawn from vertex to middle of base, as *b o*.

NOTE.—A parabola has not a conjugate diameter.

Fig. 3.



A *Hyperbola* is a figure generated by a plane cutting a cone at any angle with base greater than that of side of cone, as *a b c*, Fig. 3.

Transverse axis or diameter, *o b*, is that part of axis, *e b*, which, if continued, as at *o*, would join an opposite cone, *o f r*.

Conjugate axis or diameter is a right line drawn through centre, *g*, of transverse axis, and perpendicular to it.

Straight line through *foci* is indefinite transverse axis; that part of it between vertices of curves, as *o b*, is definite transverse axis. Its middle point, *g*, is centre of curve.

Eccentricity of a hyperbola is ratio obtained by dividing distance from centre to either *focus* by semi-transverse axis.

Parameter is cord of curve drawn through *focus* at right angles to axis.

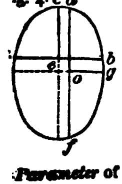
Asymptotes of a hyperbola are two right lines to which the curve continually approaches, touches at an infinite distance but does not pass; they are prolongations of diagonals of rectangle constructed on extremes of the axes.

Two hyperbolas are *conjugate* when transverse axis of one is conjugate of the other, and contrariwise.

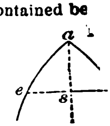
General Definitions.

An *Ordinate* is a right line from any point of a curve to either of diamete- *e* and *d o*, Fig. 4, and *a b* and *d f*, are double ordinates; *c b*, Fig. 5, is an ord nd *a b* an abscissa.

Fig. 4.



An *Abscissa* is that part of diameter which is contained be vertex and an ordinate, as *c e*, *g o*, Fig. 4, and *a b*, Fig. 5.



Parameter of any diameter is equal to four times distance from *focus* to vertex of curve; parameter of axis is least possible, and is termed parameter of curve.

Parameter of curve of a conic section is e- to chord of curve drawn through *focus* perpe ular to axis.

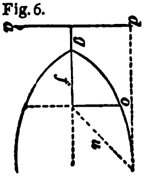
Parameter of transverse axis is least, and is termed param

Parameter of a conic section and *foci* are sufficient elen curve.

A *Focus* is a point on principal axis where double ordinate to axis, through p
is equal to parameter, as ef, Fig. 5.

It may be determined arithmetically thus: Divide square of ordinate by
times abscissa, and quotient will give focal distances, as and s, in preceding fig

Fig. 6.



Directrix of a conic section is a right line at right angl
major axis, and it is in such a position that

$$f : g :: u : o.$$

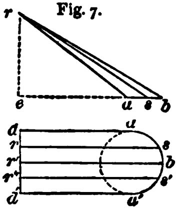
Here ad, Fig. 6, is directrix, and o is *offset* to directrix.

Latus Rectum, or principal parameter, passes through a fo
it is a double ordinate, which is a third proportion to the a

$$\text{Or, } A : a :: a : L.$$

A *and* a *representing major and minor axes.* (See *Has*
Mensuration, page 232.)

Fig. 7.



A *Conoid* is a warped surface generated by a r
line being moved in such a manner that it will t
a straight line and curve, and continue parallel
given plane. Straight line and curve are calle
rectrices, plane a plane *directrix*, and moving lin
generatrix.

Thus, let $a\,b\,a'$, Fig. 7, be a circle in a horizontal p
and $d\,d'$ projection of right lines perpendicular to a
tical plane, $r'\,b\,e$; if right lines, $d\,a$, $r\,s$, $r'\,b$, $r''\,s$, and
be moved so as to touch circle and right line $d\,d'$ a
constantly parallel to plane $r'\,b\,e$, it will generate c
$d\,a\,b\,a'\,d'$.

Radii vectores are lines drawn from the foci to any point in the curve; he
radius vector is one of these lines.

Traced angle is angle formed by the radii vectores and the transverse diame

Ellipsoid, *Paraboloid*, and *Hyperboloid of Revolution*—Figures gener
by the revolution of an ellipse, parabola, etc., around their axes. (See *M*
suration of Surfaces and Solids, pages 357-75.)

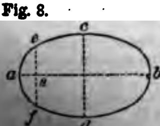
NOTE 1.—All figures which can possibly be formed by cutting of a cone are n
tioned in these definitions, and are five following—viz., a *Triangle*, a *Circle*, a
lipse, a *Parabola*, and a *Hyperbola*; but last three only are termed *Conic Secti*

2.—In *Parabola* parameter of any diameter is a third proportional to abs
and ordinate of any point of curve, abscissa and ordinate being referred to
diameter and tangent at its vertex.

3.—In *Ellipse* and *Hyperbola* parameter of any diameter is a third proporti
to diameter and its conjugate.

To Determine Parameter of an Ellipse or Hyperbol

Fig. 8.

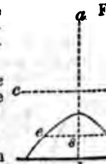


RULE.—Divide product of conjugate diameter, multiplied by itself, by transverse, and quotient is equal to parameter.

In annexed Figs. 8 and 9, of an *Ellipse* and *Hyperbola*, transverse and conjugate diameters, $a\,b$, $c\,d$, are each 30 and 20.

Then $30 : 20 :: 20 : 13.333 =$ *parameter*.

Fi



Parameter of curve $= ef$, a double ordinate passing through focus, s.

Ellipse.

...scribe Ellipses. (See Geometry, page 226.)

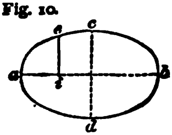
...Compute Terms of an Ellipse.

...*of fo*... *s of an Ellipse are given, viz., Tra*...
...*ate, and its Abscissa, to ascertain*...

To Compute Ordinate.

Transverse and Conjugate Diameters and Abscissa being given. RULE.—As tr verse diameter is to conjugate, so is square root of product of abscissæ to ordi which divides them.

Fig. 10.



EXAMPLE.—Transverse diameter, *a b*, of an ellipse, 10, is 25; conjugate, *c d*, 16; and abscissa, *a i*, 7; wh length of ordinate, *i e*?

$25 - 7 = 18$ *less abscissa*; $\sqrt{7 \times 18} = 11.225$.
Hence $25 : 16 :: 11.225 : 7.184$ *ordinate.*

Or, $\sqrt{c^2 - \left(\frac{c\,x}{t}\right)^2}$ = *any ordinate, c and t represen semi-conjugate and transverse diameters, and x distance of ordinate from centr figure.*

To Compute Abscissæ.

Transverse and Conjugate Diameters and Ordinate being given. RULE.—As co gate diameter is to transverse, so is square root of difference of squares of ordi and semi-conjugate to distance between ordinate and centre; and this distanc ing added to, or subtracted from, semi-transverse, will give abscissæ required.

EXAMPLE.—Transverse diameter, *a b*, of an ellipse, Fig. 10, is 25; conjugate, 16; and ordinate, *i e*, 7.184; what is abscissa, *i b*?

$$\sqrt{8^2 - 7.184^2} = 3.519\,943. \text{ Hence, as } 16 : 25 :: 3.52 : 5.5.$$

Then $\left.\begin{array}{l} 25 \div 2 = 12.5, \text{ and } 12.5 + 5.5 = 18 = b\ i, \\ 25 \div 2 = 12.5, \text{ and } 12.5 - 5.5 = \ \ 7 = a\ i, \end{array}\right\}$ *abscissæ.*

To Compute Transverse Diameter.

Conjugate, Ordinate, and Abscissa being given. RULE.—To or from semi-co gate, according as great or less abscissa is used, add or subtract square root of ference of squares of ordinate and semi-conjugate. Then, as this sum or differ is to abscissa, so is conjugate to transverse.

EXAMPLE.—Conjugate diameter, *c d*, of an ellipse, Fig. 10, is 16; ordinate 7.184; and abscissæ, *b i*, *i a*, 18 and 7; what is length of transverse diameter?

$$\sqrt{(16 \div 2)^2 - 7.184^2} = 3.52.$$

$16 \div 2 + 3.52 : 18 :: 16 : 25$; $16 \div 2 - 3.52 : 7 :: 16 : 25$ *transverse diameter*

To Compute Conjugate Diameter.

Transverse, Ordinate, and Abscissa being given. RULE.—As square root of p uct of abscissæ is to ordinate, so is transverse diameter to conjugate.

EXAMPLE.—Transverse diameter, *a b*, of an ellipse, Fig. 10, is 25; ordinate 7.184; and abscissæ, *b i* and *i a*, 18 and 7; what is length of conjugate diamete

$\sqrt{18 \times 7} = 11.225$. Hence $11.225 : 7.184 :: 25 : 16$ *conjugate diameter.*

To Compute Circumference of an Ellipse.

RULE.—Multiply square root of half sum of the squares of two diameter 3.1416.

EXAMPLE.—Transverse and conjugate diameters, *a b* and *c d*, of an ellipse, Fi are 24 and 20; what is its circumference?

$\frac{24^2 + 20^2}{2} = 488$, and $\sqrt{488} = 22.09$. Hence $22.09 \times 3.1416 = 69.398$ *circumfe*

To Compute Area of an Ellipse.

RULE.—Multiply the diameters together, and the product by .7854. O one diameter by .7854, and the product by the other.

EXAMPLE.—The transverse diameter of an ellipse, *a b*, Fig jugate, *c d*, 9; what is its area?

$$12 \times 9 \times .7854 = 84.8232 \textit{ area.}$$

NOTE.—Area of an ellipse is a mean proportional betwe diameter of one being major axis and of the other minor ax

ILLUSTRATION.—*Area of circle of* $40 = 1256.64$; area of c *area of circle of* $20 = 314.16$, mean of the two circles 12 *Therefore the conjugate* diameter of an ellipse of an area of *being 40, is 25 feet, as* $40 \times 25 \times .7854 = 785.4$ sq. ins.

To Compute Transverse Diameter,

Conjugate, Ordinate, and an Abscissa being given. RULE.—Add square of o to square of semi-conjugate, and extract square root of their sum.

Take sum or difference of semi-conjugate and this root, according as gre lesser abscissa is used. Then, as square of ordinate is to product of absci conjugate, so is sum or difference above ascertained to transverse diameter re

NOTE.—When the greater abscissa is used, the difference is taken, a trariwise.

EXAMPLE.—Conjugate diameter, *d f*, of a hyperbola, Fig. 15, is 72; ordin 48; and lesser abscissa, *a e*, 40; what is length of transverse diameter, *a t*?

$\sqrt{48^2 + (72 \div 2)^2} = 60$, and $60 + \overline{72 \div 2} = 96$ *lesser abscissa*, and $40 \times 72 =$
Hence, $48^2 : 2880 :: 96 : 120$ *transverse diameter.*

To Compute Length of any Arc of a Hyperbola, mencing at Vertex.

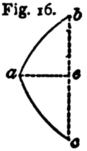
RULE.—To 19 times transverse diameter add 21 times parameter of axis.

To 9 times transverse diameter add 21 times parameter, and multiply these sums respectively by quotient of lesser abscissa divided by transve ameter.

To each of products thus ascertained add 15 times parameter, and divide by latter; then this quotient, multiplied by ordinate, will give length of arc,

NOTE.—*To Compute Parameter,* divide square of conjugate by transverse eter.

Fig. 16.



EXAMPLE.—In hyperbola, *a b c*, Fig. 16, transverse diameter conjugate, 72, ordinate, *e c*, 48, and lesser abscissa, *a e*, 40; length of arc, *a b*?

$\frac{72^2}{120} = 43.2$ *parameter.* $\overline{120 \times 19} + \overline{43.2 \times 21} \times \frac{40}{120} = 1062.$

$\overline{120 \times 9} + \overline{43.2 \times 21} \times \frac{40}{120} = 662.4.$ Then $1062.4 + \overline{43.2 \times 15}$

$+ \overline{43.2 \times 15} = 1.305$, which $\times 48 = 62.64$ *length.*

NOTE.—As transverse diameter is to conjugate, so is conjugate to par (See Rule, page 380.)

To Compute Area of a Hyperbola,

Transverse, Conjugate, and Lesser Abscissa being given. RULE.—To pro transverse diameter and lesser abscissa add five sevenths of square of this a and multiply square root of sum by 21.

Add 4 times square root of product of transverse diameter and lesser abs product last ascertained, and divide sum by 75.

Divide 4 times product of conjugate diameter and lesser abscissa by tra diameter, and this last quotient, multiplied by former, will give area, nearly.

EXAMPLE.—Transverse diameter of a hyperbola, Fig. 16, is 60, conjugate lesser abscissa or height, *a e*, 20; what is area of figure?

$60 \times 20 + \frac{5}{7}$ of $20^2 = 1485.7143$, and $\sqrt{1485.7143} \times 21 = 809.43$, and $\sqrt{60}$

$4 + 809.43 = 901.02$, which $\div 75 = 12.0136$ and $\frac{36 \times 20 \times 4}{60} \times 12.0136 = 576.65$

For ordinates of a parabola in divisions of eighths and tenths, see page 229.

Delta Metal.

etal is an improved composition of Aluminium and its alloys osive, capable of being cast, forged, and hot rolled.

Tensile Strength per Sq. Inch.

[illegible] sand	48 380 lbs.	Rolled, annealed	60[illegible]
[illegible]	75 260 "	Wire, No. 22 W G	140[illegible]

PLANE TRIGONOMETRY.

By *Plane Trigonometry* is ascertained how to compute or determine ur of the seven elements of a plane or rectilinear triangle from the her three, for when any three of them are given, one of which being side or the area, the remaining elements may be determined; and iis operation is termed *Solving the Triangle.*

The determination of the mutual relation of the Sines, Tangents, Secants, c., of the sums, differences, multiples, etc., of arcs or angles is also classed nder this head.

For Diagram and Explanation of Terms, see Geometry, pp. 219–21.

Right-angled Triangles.

For Solution by Lines and Areas, see Mensuration of Areas, Lines, ıd Surfaces, pp. 335–39.

To Compute a Side.

When a Side and its Opposite Angle is given. RULE.—As sine of angle pposite given side is to sine of angle opposite required side, so is given side required side.

To Compute an Angle.

RULE.—As side opposite to given angle is to side opposite to required ıgle, so is sine of given angle to sine of required angle.

'o Compute Base or Perpendicular in a Right-angled Triangle.

When Angles and One Side next Right Angle are given. RULE.—As ra- .us is to tangent of angle adjacent to given side, so is this side to other side.

To Compute the other Side.

When Two Sides and Included Angle are given. RULE.—As sum of two iven sides is to their difference, so is tangent of half sum of their opposite ıgles to tangent of half their difference; add this half difference to half ım, to ascertain greater angle; and subtract half difference from half sum, ascertain less angle. The other side may then be ascertained by Rule ove.

To Compute Angles.

When Sides are given. RULE.—As one side is to other side, so is radius tangent of angle adjacent to first side.

To Compute an Angle.

When Three Sides are given. RULE 1.—Subtract sum of logarithı ides which contain required angle, from 20; to remainder add loga f half sum of three sides, and that of difference between this half sun. ide opposite to required angle. Half the sum of these three logarithn garithmic cosine of half required angle. The other angles may be as ained by Rule above.

2.—Subtract sum of logarithms of two sides ... in require ngle, from 20, and to remainder add logarithr ... hese two sides and half sum of the three sides. ine of half required angle.

NOTE.—In all ordinary cases either of these rules w ults. Rule 1 should be used when required angle e1 less than 90°.

EXAMPLE.—The sides of a triangle are 3, 4, and 5; what are the angles of th hypothenuse?

$20 - (\text{Log. } 4 = .602\,06 + \text{Log. } 5 = .698\,97) = 18.698\,97$; $\text{Log. } 3 + 4 + 5 \div 2 - 4 = .301\,03$; and $\text{Log. } 3 + 4 + 5 \div 2 - 5 = 0$.

Then $18.698\,97 + .301\,03 = 19$, which $\div 2 = 9.5 =$ log. sin. of half angle $= 18^\circ\ 26'$, which $\times 2 = 36^\circ\ 52'$ *angle*.

Hence $90^\circ - 36^\circ\ 52' = 53^\circ\ 8'$ *remaining angle*.

In following figures, 1 and 2:

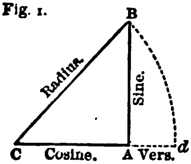
$A = 90^\circ$, $B = 45^\circ$, $C = 45^\circ$, Radius $= 1$, Secant $= 1.4142$, Cosine $= .7071$, Sin. $45^\circ = .7071$, Tangent $= 1$, Area $= .25$.

By Sin., Tan., Sec., etc., A B, etc., is expressed Sine, Tangent, Secant, etc., of angles, A, B, etc.

To Compute Sides A C and B C.—Figs. 1 and 2.

When Hyp., Side B A, *and Angles* B *and* C *are given.*

Fig. 1.



$$\frac{\text{Sin. B} \times \text{B A}}{\text{Sin. C}} = \text{A C}.$$

$$\text{B A} \times \text{Cot. C} = \text{A C}.$$

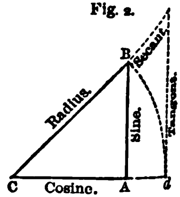
$$\text{Hyp.} \times \text{Cos. C} = \text{A C}.$$

$$\text{Hyp.} \times \text{Sin. B} = \text{A C}.$$

$$\frac{\text{B A}}{\text{Sin. C}} = \text{B C}.$$

$$\frac{\text{A C}}{\text{Sin. B}} = \text{B C}.$$

Fig. 2.



To Compute Side A C and Angles.

When Hyp. and Side B A *are given.*—Fig. 1 and 2.

$$\frac{\text{A C}}{\text{Hyp.}} = \text{Sin. B}. \qquad \frac{\text{B A}}{\text{Hyp.}} = \text{Sin. C}. \qquad \frac{\text{B A} \times \text{Sin. B}}{\text{Sin. C}} = \text{A C}. \qquad \text{B C} \times \text{Sin. B} = \text{A C}$$

To Compute Side B C and Hyp. or Angles.

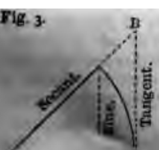
When both Sides are given.—Fig. 2.

$$\frac{\text{A C}}{\text{B A}} = \text{Tan. B}. \qquad \frac{\text{B A}}{\text{Sin. C}} = \text{B C}. \qquad \sqrt{\text{A C}^2 + \text{B A}^2} = \text{B C}. \qquad \frac{\text{B A}}{\text{A C}} = \text{Tan. C}$$

$$\frac{\text{B A}}{\text{B C}} = \text{Sin. C}. \qquad \frac{\text{A C}}{\text{B C}} = \text{Sin. B}.$$

To Compute Sides.—Figs. 3 and 4.

Fig. 3.



When a Side and an Angle are given.

$$\text{B C} \times \text{Cos. B} = \text{B A}.$$

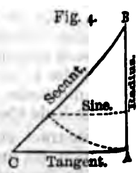
$$\text{B C} \times \text{Sin. B} = \text{A C}.$$

$$\text{A B} \times \text{Sec. B} = \text{B C}.$$

$$\frac{\text{A C} \times \text{Tan. C}}{\text{Rad.}} = \text{B A}. \qquad \frac{\text{A C} \times \text{Sin. C}}{\text{Sin. B}} = \text{B A}.$$

$$\frac{\text{A C} \times \text{Sec. C}}{\text{Rad.}} = \text{B C}. \qquad \frac{\text{A C} \times \text{Rad.}}{\text{Sin. B}} = \text{B C}.$$

Fig. 4.

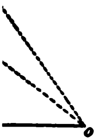


... a right-angled triangle, C A, is assumed to be radius ... and B C ... to that radius; Or, dividing each of the ... nt and secant of C respectively to radi...

′	4° N. sine.	4° N. cos.	5° N. sine.	5° N. cos.	6° N. sine.	6° N. cos.	7° N. sine.	7° N. cos.	′	Prop. parts 4
0	.06976	.99756	.08716	.99619	.10453	.99452	.12187	.99255	60	4
1	.07005	.99754	.08745	.99617	.10482	.99449	.12216	.99251	59	4
2	.07034	.99752	.08774	.99614	.10511	.99446	.12245	.99248	58	4
3	.07063	.9975	.08803	.99612	.1054	.99443	.12274	.99244	57	4
4	.07092	.99748	.08831	.99609	.10569	.9944	.12302	.9924	56	4
5	.07121	.99746	.0886	.99607	.10597	.99437	.12331	.99237	55	4
6	.0715	.99744	.08889	.99604	.10626	.99434	.1236	.99233	54	4
7	.07179	.99742	.08918	.99602	.10655	.99431	.12389	.9923	53	4
8	.07208	.9974	.08947	.99599	.10684	.99428	.12418	.99226	52	3
9	.07237	.99738	.08976	.99596	.10713	.99424	.12447	.99222	51	3
10	.07266	.99736	.09005	.99594	.10742	.99421	.12476	.99219	50	3
11	.07295	.99734	.09034	.99591	.10771	.99418	.12504	.99215	49	3
12	.07324	.99731	.09063	.99588	.108	.99415	.12533	.99211	48	3
13	.07353	.99729	.09092	.99586	.10829	.99412	.12562	.99208	47	3
14	.07382	.99727	.09121	.99583	.10858	.99409	.12591	.99204	46	3
15	.07411	.99725	.0915	.9958	.10887	.99406	.1262	.992	45	3
16	.0744	.99723	.09179	.99578	.10916	.99402	.12649	.99197	44	3
17	.07469	.99721	.09208	.99575	.10945	.99399	.12678	.99193	43	3
18	.07498	.99719	.09237	.99572	.10973	.99396	.12706	.99189	42	3
19	.07527	.99716	.09266	.9957	.11002	.99393	.12735	.99186	41	3
20	.07556	.99714	.09295	.99567	.11031	.9939	.12764	.99182	40	3
21	.07585	.99712	.09324	.99564	.1106	.99386	.12793	.99178	39	3
22	.07614	.9971	.09353	.99562	.11089	.99383	.12822	.99175	38	3
23	.07643	.99708	.09382	.99559	.11118	.9938	.12851	.99171	37	2
24	.07672	.99705	.09411	.99556	.11147	.99377	.1288	.99167	36	2
25	.07701	.99703	.0944	.99553	11176	.99374	.12908	.99163	35	2
26	.0773	.99701	.09469	.99551	.11205	.9937	.12937	.9916	34	2
27	.07759	.99699	.09498	.99548	.11234	.99367	.12966	.99156	33	2
28	.07788	.99696	.09527	.99545	.11263	.99364	.12995	.99152	32	2
29	.07817	.99694	.09556	.99542	.11291	.9936	.13024	.99148	31	2
30	.07846	.99692	.09585	.9954	.1132	.99357	13053	.99144	30	2
31	.07875	.99689	.09614	.99537	.11349	.99354	13081	.99141	29	2
32	.07904	.99687	.09642	.99534	.11378	.99351	.1311	.99137	28	2
33	.07933	.99685	.09671	.99531	.11407	.99347	.13139	.99133	27	2
34	.07962	.99683	.097	.99528	.11436	.99344	.13168	.99129	26	2
35	.07991	.9968	.09729	.99526	.11465	.99341	.13197	.99125	25	2
36	.0802	.99678	.09758	.99523	.11494	.99337	.13226	.99122	24	2
37	.08049	.99676	.09787	.9952	.11523	.99334	.13254	.99118	23	2
38	.08078	.99673	.09816	.99517	.11552	.99331	.13283	.99114	22	1
39	.08107	.99671	.09845	.99514	.1158	.99327	.13312	.9911	21	1
40	.08136	.99668	.09874	.99511	.11609	.99324	.13341	.99106	20	1
41	.08165	.99666	.09903	.99508	.11638	.9932	.1337	.99102	19	1
42	.08194	.99664	.09932	.99506	.11667	.99317	.13399	.99098	18	1
43	.08223	.99661	.09961	.99503	.11696	.99314	13427	.99094	17	1
44	.08252	.99659	.0999	.995	.11725	.9931	.13456	.99091	16	1
45	.08281	.99657	.10019	.99497	.11754	.99307	.13485	.99087	15	1
46	.0831	.99654	.10048	.99494	11783	.99303	.13514	.99083	14	1
47	.08339	.99652	10077	.99491	.11812	.993	.13543	.99079	13	1
48	.08368	.99649	.10106	.99488	.1184	.99297	.13572	.99075	12	1
49	.08397	.99647	.10135	.99485	.11869	.99293	.136	.99071	11	1
50	.08426	.99644	.10164	.99482	.11898	.9929	.13629	.99067	10	1
51	.08455	.99642	.10192	.99479	.11927	99286	.13658	.99063	9	1
52	.08484	.99639	.10221	.99476	.11956	.99283	.13687	.99059	8	1
53	.08513	.99637	.1025	.99473	.11985	.99279	.13716	.99055	7	0
54	.08542	.99635	.10279	.9947	.12014	.99276	.13744	.99051	6	0
55	.08571	.99632	.10308	.99467	.12043	.99272	.13773	.99047	5	0
56	.086	.9963	.10337	.99464	.12071	.99269	.13802	.99043	4	0
57	.08629	.99627	.10366	.99461	.121	.99265	.13831	.99039	3	0
58	.08658	.99625	.10395	.99458	.12129	.99262	.1386	.99035	2	0
59	.08687	.99622	.10424	.99455	.12158	.99258	.13889	99031	1	0
60	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	0	0
′	N. cos. 85°	N. sine. 85°	N. cos. 84°	N. sine. 84°	N. cos. 83°	N. sine. 83°	N. cos. 82°	N. sine. 82°	′	

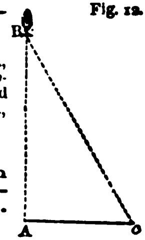
Prop. parts. 28	′	8° N. sine.	8° N. cos.	9° N. sine.	9° N. cos.	10° N. sine.	10° N. cos.	11° N. sine.	11° N. cos.	
0	0	.13917	.99027	.15643	.98769	.17365	.98481	.19081	.98163	60
0	1	.13946	.99023	.15672	.98764	.17393	.98476	.19109	.98157	59
1	2	.13975	.99019	.15701	.9876	.17422	.98471	.19138	.98152	58
1	3	.14004	.99015	.1573	.98755	.17451	.98466	.19167	.98146	57
2	4	.14033	.99011	.15758	.98751	.17479	.98461	.19195	.9814	56
2	5	.14061	.99006	.15787	.98746	.17508	.98455	.19224	.98135	55
3	6	.1409	.99002	.15816	.98741	.17537	.9845	.19252	.98129	54
3	7	.14119	.98998	.15845	.98737	.17565	.98445	.19281	.98124	53
4	8	.14148	.98994	.15873	.98732	.17594	.9844	.19309	.98118	52
4	9	.14177	.9899	.15902	.98728	.17623	.98435	.19338	.98112	51
5	10	.14205	.98986	.15931	.98723	.17651	.9843	.19366	.98107	50
5	11	.14234	.98982	.15959	.98718	.1768	.98425	.19395	.98101	49
6	12	.14263	.98978	.15988	.98714	.17708	.9842	.19423	.98096	48
6	13	.14292	.98973	.16017	.98709	.17737	.98414	.19452	.9809	47
7	14	.1432	.98969	.16046	.98704	.17766	.98409	.19481	.98084	46
7	15	.14349	.98965	.16074	.987	.17794	.98404	.19509	.98079	45
7	16	.14378	.98961	.16103	.98695	.17823	.98399	.19538	.98073	44
8	17	.14407	.98957	.16132	.9869	.17852	.98394	.19566	.98067	43
8	18	.14436	.98953	.1616	.98686	.1788	.98389	.19595	.98061	42
9	19	.14464	.98948	.16189	.98681	.17909	.98383	.19623	.98056	41
9	20	.14493	.98944	.16218	.98676	.17937	.98378	.19652	.9805	40
10	21	.14522	.9894	.16246	.98671	.17966	.98373	.1968	.98044	39
10	22	.14551	.98936	.16275	.98667	.17995	.98368	.19709	.98039	38
11	23	.1458	.98931	.16304	.98662	.18023	.98362	.19737	.98033	37
11	24	.14608	.98927	.16333	.98657	.18052	.98357	.19766	.98027	36
12	25	.14637	.98923	.16361	.98652	.18081	.98352	.19794	.98021	35
12	26	.14666	.98919	.1639	.98648	.18109	.98347	.19823	.98016	34
13	27	.14695	.98914	.16419	.98643	.18138	.98341	.19851	.9801	33
13	28	.14723	.9891	.16447	.98638	.18166	.98336	.1988	.98004	32
14	29	.14752	.98906	.16476	.98633	.18195	.98331	.19908	.97988	31
14	30	.14781	.98902	.16505	.98629	.18224	.98325	.19937	.97992	30
14	31	.1481	.98897	.16533	.98624	.18252	.9832	.19965	.97987	29
15	32	.14838	.98893	.16562	.98619	.18281	.98315	.19994	.97981	28
15	33	.14867	.98889	.16591	.98614	.18309	.9831	.20022	.97975	27
16	34	.14896	.98884	.1662	.98609	.18338	.98304	.20051	.97969	26
16	35	.14925	.9888	.16648	.98604	.18367	.98299	.20079	.97963	25
17	36	.14954	.98876	.16677	.986	.18395	.98294	.20108	.97958	24
17	37	.14982	.98871	.16706	.98595	.18424	.98288	.20136	.97952	23
18	38	.15011	.98867	.16734	.9859	.18452	.98283	.20165	.97946	22
18	39	.1504	.98863	.16763	.98585	.18481	.98277	.20193	.9794	21
19	40	.15069	.98858	.16792	.9858	.18509	.98272	.20222	.97934	20
19	41	.15097	.98854	.1682	.98575	.18538	.98267	.2025	.97928	19
20	42	.15126	.98849	.16849	.9857	.18567	.98261	.20279	.97922	18
20	43	.15155	.98845	.16878	.98565	.18595	.98256	.20307	.97916	17
21	44	.15184	.98841	.16906	.98561	.18624	.9825	.20336	.9791	16
21	45	.15212	.98836	.16935	.98556	.18652	.98245	.20364	.97905	15
21	46	.15241	.98832	.16964	.98551	.18681	.9824	.20393	.97899	14
22	47	.1527	.98827	.16992	.98546	.1871	.98234	.20421	.97893	13
22	48	.15299	.98823	.17021	.98541	.18738	.98229	.2045	.97887	12
23	49	.15327	.98818	.1705	.98536	.18767	.98223	.20478	.97881	11
23	50	.15356	.98814	.17078	.98531	.18795	.98218	.20507	.97875	10
24	51	.15385	.98809	.17107	.98526	.18824	.98212	.20535	.97869	9
24	52	.15414	.98805	.17136	.98521	.18852	.98207	.20563	.97863	8
25	53	.15442	.988	.17164	.98516	.18881	.98201	.20592	.97857	7
25	54	.15471	.98796	.17193	.98511	.1891	.98196	.2062	.97851	6
26	55	.155	.98791	.17222	.98506	.18938	.9819	.20649	.97845	5
26	56	.15529	.98787	.1725	.98501	.18967	.98185	.20677	.97839	4
27	57	.15557	.98782	.17279	.98496	.18995	.98179	.20706	.97833	3
27	58	.15586	.98778	.17308	.98491	.19024	.98174	.20734	.97827	2
28	59	.15615	.98773	.17336	.98486	.19052	.98168	.20763	.97821	1
28	60	.15643	.98769	.17365	.98481	.19081	.98163	.20791	.97815	0
		N. cos. 81°	N. sine. 81°	N. cos. 80°	N. sine. 80°	N. cos. 79°	N. sine. 79°	N. cos. 78°	N. sine. 78°	′

; 11.



When the Objects can be aligned.—Fig. 11.

Fig. 12.



OPERATION.—Align *c* B, Fig. 11, at A, measure a base line at any angle thereto, as A *o*, and angles *o* A *c*, *c o* A, and B *o* A. Then proceed as per formula, page 386, to deduce *c* B.

To Compute Distance from a Given Point to an Inaccessible Object.—Fig. 12.

r.—Measure a level line, A *c*, Fig. 12, and ascertain angles, B A *c*, B *c* A. ng side, A *c*, and two angles, proceed as per formula, page 386, to de-
l.

mpute Height of an Elevated Point.—Fig. 13.

Fig. 13.

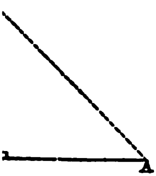
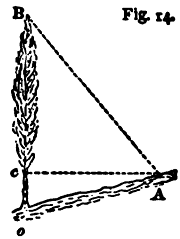


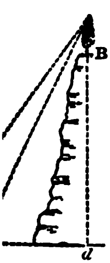
Fig. 14.



OPERATION. — Measure distance on a horizontal line, A *c*, Fig. 13; ascertain Angle B A *c*. Then proceed as per formulas, pp. 386–8, to ascertain B *c*.

When a Horizontal Base is not Attainable.—Fig. 14.

OPERATION.—Measure or compute distance A *c*, Fig.
In angle of depression *c* A *o* and of elevation
n proceed as per formula, page 386, to ascertain B *c*.

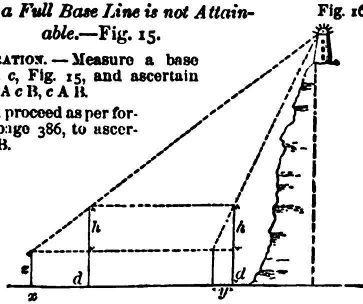


When a Full Base Line is not Attainable.—Fig. 15.

OPERATION. — Measure a base line, A *c*, Fig. 15, and ascertain angles A *c* B, *c* A B.

Then proceed as per formula, page 386, to ascertain *d* B.

Fig. 16.



's of an Instrument.—Fig. 16.

t.—Lay off any suitable and level distance, *d d*, set up *s* -levation from base line *d d*, and note distances of object range with tops of the staffs; deduct d ascertain heights *h*.

+ *s* = *height*. *s representing height of line of* *sd.*

Natural Sines and Cosines.

Prop. parts.		0°		1°		2°		3°		
29	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	
0	0	.00000	1	.01745	.99985	0349	.99939	.05234	.99863	60
0	1	.00029	1	.01774	.99984	.03519	.99938	.05263	.99861	59
1	2	.00058	1	01803	.99984	.03548	.99937	.05292	.9986	58
1	3	.00087	1	.01832	.99983	.03577	.99936	.05321	.99858	57
2	4	.00116	1	.01862	.99983	03606	.99935	.0535	.99857	56
2	5	.00145	1	.01891	.99982	03635	.99934	.05379	.99855	55
3	6	.00175	1	.0192	.99982	.03664	.99933	.05408	.99854	54
3	7	.00204	1	.01949	.99981	.03693	.99932	.05437	.99852	53
4	8	.00233	1	.01978	.9998	.03723	.99931	.05466	.99851	52
4	9	.00262	1	.02007	.9998	.03752	.9993	.05495	.99849	51
5	10	.00291	1	.02036	.99979	03781	.99929	.05524	.99847	50
5	11	.0032	.99999	.02065	.99979	.0381	.99927	.05553	.99846	49
6	12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	48
6	13	.00378	.99999	.02123	.99977	03868	.99925	.05611	.99842	47
7	14	.00407	.99999	.02152	.99977	.03897	.99924	.0564	.99841	46
7	15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	45
8	16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	44
8	17	.00495	.99999	.0224	.99975	.03984	.99921	.05727	.99836	43
9	18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	42
9	19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	41
10	20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	40
10	21	.00611	.99998	.02356	.99972	.041	.99916	.05844	.99829	39
11	22	.0064	.99998	.02385	.99972	.04129	99915	.05873	.99827	38
11	23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	37
12	24	.00698	.99998	.02443	.9997	.04188	.99912	.05931	.99824	36
12	25	.00727	.99997	.02472	.99969	.04217	.99911	.0596	.99822	35
13	26	.00756	.99997	.02501	.99969	.04246	.9991	.05989	.99821	34
13	27	.00785	.99997	.0253	.99968	.04275	.99909	.06018	.99819	33
14	28	.00814	.99997	.0256	.99967	.04304	.99907	.06047	.99817	32
14	29	.00844	.99996	.02589	.99966	.04333	.99906	.06076	.99815	31
15	30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	.99813	30
15	31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	29
15	32	.00931	.99996	.02676	.99964	.0442	.99902	.06163	.9981	28
16	33	.0096	.99995	.02705	.99963	.04449	.99901	.06192	.99808	27
16	34	.00989	.99995	.02734	.99963	.04478	.999	.06221	.99806	26
17	35	01018	.99995	.02763	.99962	.04507	.99898	.0625	.99804	25
17	36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	24
18	37	.01076	.99994	.02821	.9996	.04565	.99896	.06308	.99801	23
18	38	.01105	.99994	.0285	.99959	.04594	.99894	.06337	.99799	22
19	39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	21
19	40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	20
20	41	.01193	.99993	.02938	.99957	.04682	.9989	.06424	.99793	19
20	42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	18
21	43	.01251	.99992	02996	.99955	.0474	.99888	.06482	.9979	17
21	44	.0128	.99992	.03025	.99954	.04769	.99886	.06511	.99788	16
22	45	01309	.99991	.03054	.99953	.04798	.99885	.0654	.99786	15
22	46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	14
23	47	.01367	.99991	.03112	.99952	.04856	.99882	06598	.99782	13
23	48	.01396	.9999	.03141	.99951	.04885	.99881	.06627	.9978	12
24	49	.01425	.9999	.0317	.9995	.04914	.99879	.06656	.99778	11
24	50	.01454	.99989	.03199	.99949	04943	.99878	06685	.99776	10
25	51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	9
25	52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	8
26	53	[illegible]	.99988	.03286	.99946	.0503	.99873	.06773	.9977	7
26	[illegible]	[illegible]	.99988	.03316	.99945	.05059	.99872	.06802	.99768	6
[illegible]	[illegible]	[illegible]	[illegible]	.03345	.99944	.05088	.9987	.06831	.99766	5
[illegible]	[illegible]	[illegible]	[illegible]	.03374	.99943	.05117	.99869	.0686	.99764	4
[illegible]	[illegible]	[illegible]	[illegible]	.03403	.99942	.05146	.99867	.06889	.99762	3
[illegible]	[illegible]	[illegible]	[illegible]	.03432	.99941	.05175	.99866	.06918	.9976	2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.05205	.99864	.06947	.99758	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.05234	.99863	.06976	.99756	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	N. cos.	[illegible]	N. cos.	N. sine	

′	4° N. sine.	4° N. cos.	5° N. sine.	5° N. cos.	6° N. sine.	6° N. cos.	7° N. sine.	7° N. cos.		Prop. parts 4
0	.06976	.99756	.08716	.99619	.10453	.99452	.12187	.99255	60	4
1	.07005	.99754	.08745	.99617	.10482	.99449	.12216	.99251	59	4
2	.07034	.99752	.08774	.99614	.10511	.99446	.12245	.99248	58	4
3	.07063	.9975	.08803	.99612	.1054	.99443	.12274	.99244	57	4
4	.07092	.99748	.08831	.99609	.10569	.9944	.12302	.9924	56	4
5	.07121	.99746	.0886	.99607	.10597	.99437	.12331	.99237	55	4
6	.0715	.99744	.08889	.99604	.10626	.99434	.1236	.99233	54	4
7	.07179	.99742	.08918	.99602	.10655	.99431	.12389	.9923	53	4
8	.07208	.9974	.08947	.99599	.10684	.99428	.12418	.99226	52	3
9	.07237	.99738	.08976	.99596	.10713	.99424	.12447	.99222	51	3
10	.07266	.99736	.09005	.99594	.10742	.99421	.12476	.99219	50	3
11	.07295	.99734	.09034	.99591	.10771	.99418	.12504	.99215	49	3
12	.07324	.99731	.09063	.99588	.108	.99415	.12533	.99211	48	3
13	.07353	.99729	.09092	.99586	.10829	.99412	.12562	.99208	47	3
14	.07382	.99727	.09121	.99583	.10858	.99409	.12591	.99204	46	3
15	.07411	.99725	.0915	.9958	.10887	.99406	.1262	.992	45	3
16	.0744	.99723	.09179	.99578	.10916	.99402	.12649	.99197	44	3
17	.07469	.99721	.09208	.99575	.10945	.99399	.12678	.99193	43	3
18	.07498	.99719	.09237	.99572	.10973	.99396	.12706	.99189	42	3
19	.07527	.99716	.09266	.9957	.11002	.99393	.12735	.99186	41	3
20	.07556	.99714	.09295	.99567	.11031	.9939	.12764	.99182	40	3
21	.07585	.99712	.09324	.99564	.1106	.99386	.12793	.99178	39	3
22	.07614	.9971	.09353	.99562	.11089	.99383	.12822	.99175	38	3
23	.07643	.99708	.09382	.99559	.11118	.9938	.12851	.99171	37	2
24	.07672	.99705	.09411	.99556	.11147	.99377	.1288	.99167	36	2
25	.07701	.99703	.0944	.99553	11176	.99374	.12908	.99163	35	2
26	.0773	.99701	.09469	.99551	.11205	.9937	.12937	.9916	34	2
27	.07759	.99699	.09498	.99548	.11234	.99367	.12966	.99156	33	2
28	.07788	.99696	.09527	.99545	.11263	.99364	.12995	.99152	32	2
29	.07817	.99694	.09556	.99542	.11291	.9936	.13024	.99148	31	2
30	.07846	.99692	.09585	.9954	.1132	.99357	13053	.99144	30	2
31	.07875	.99689	.09614	.99537	.11349	.99354	13081	.99141	29	2
32	.07904	.99687	.09642	.99534	.11378	.99351	.1311	.99137	28	2
33	.07933	.99685	.09671	.99531	.11407	.99347	.13139	.99133	27	2
34	.07962	.99683	.097	.99528	.11436	.99344	.13168	.99129	26	2
35	.07991	.9968	.09729	.99526	.11465	.99341	.13197	.99125	25	2
36	.0802	.99678	.09758	.99523	.11494	.99337	.13226	.99122	24	2
37	.08049	.99676	.09787	.9952	.11523	.99334	.13254	.99118	23	2
38	.08078	.99673	.09816	.99517	.11552	.99331	.13283	.99114	22	1
39	.08107	.99671	.09845	.99514	.1158	.99327	.13312	.9911	21	1
40	.08136	.99668	.09874	.99511	.11609	.99324	.13341	.99106	20	1
41	.08165	.99666	.09903	.99508	.11638	.9932	.1337	.99102	19	1
42	.08194	.99664	.09932	.99506	.11667	.99317	.13399	.99098	18	1
43	.08223	.99661	.09961	.99503	.11696	.99314	13427	.99094	17	1
44	.08252	.99659	.0999	.995	.11725	.9931	.13456	.99091	16	1
45	.08281	.99657	.10019	.99497	.11754	.99307	.13485	.99087	15	1
46	.0831	.99654	.10048	.99494	11783	.99303	.13514	.99083	14	1
47	.08339	.99652	.10077	.99491	.11812	.993	.13543	.99079	13	1
48	.08368	.99649	.10106	.99488	.1184	.99297	.13572	.99075	12	1
49	.08397	.99647	.10135	.99485	.11869	.99293	.136	.99071	11	1
50	.08426	.99644	.10164	.99482	.11898	.9929	.13629	.99067	10	
51	.08455	.99642	.10192	.99479	.11927	99286	.13658	.99063	9	
52	.08484	.99639	.10221	.99476	.11956	.99283	.13687	.99059	8	
53	.08513	.99637	.1025	.99473	.11985	.99279	.13716	.99055	7	
54	.08542	.99635	.10279	.9947	.12014	.99276	.13744	[illegible]		
	[illegible]	.99632	.10308	.99467	.12043	.99272	.13773	[illegible]		
		.9963	.10337	.99464	.12071	.99269	.13802	[illegible]		
		.99627	.10366	.99461	.121	.99265	.13831			
		.99625	.10395	.99458	.12129	.99262	.1386			
		[illegible]	.10424	.99455	.12158	.99258	.13889			
		[illegible]	.10453	.99452	.12187	.99255	.13917			
		[illegible]	N. cos. 84°	N. sine. 84°	N. cos. 83°	N. sine. 83°	N. cos. 82°	[illegible]		

Prop. parts		24°		25°		26°		27°			Prop. parts
26	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.		11
0	0	.40674	.91355	.42262	.90631	.43837	.89879	.45399	.89101	60	14
0	1	.407	.91343	.42288	.90618	.43863	.89867	.45425	.89087	59	14
1	2	.40727	.91331	.42315	.90606	.43889	.89854	.45451	.89074	58	14
1	3	.40753	.91319	.42341	.90594	.43916	.89841	.45477	.89061	57	13
2	4	.4078	.91307	.42367	.90582	.43942	.89828	.45503	.89048	56	13
2	5	.40806	.91295	.42394	.90569	.43968	.89816	45529	.89035	55	13
3	6	.40833	.91283	.4242	.90557	.43994	.89803	.45554	89021	54	13
3	7	.4086	.91272	.42446	.90545	.4402	.8979	4558	.89008	53	12
3	8	.40886	.9126	.42473	.90532	.44046	.89777	.45606	.88995	52	12
4	9	.40913	.91248	.42499	.9052	.44072	.89764	.45632	.88981	51	12
4	10	.40939	.91236	.42525	.90507	.44098	.89752	.45658	.88968	50	12
5	11	.40966	.91224	.42552	.90495	.44124	.89739	.45684	.88955	49	11
5	12	.40992	.91212	.42578	.90483	.44151	.89726	.4571	.88942	48	11
6	13	.41019	.912	.42604	.9047	.44177	.89713	.45736	.88928	47	11
6	14	.41045	.91188	.42631	.90458	.44203	.897	.45762	.88915	46	11
7	15	.41072	.91176	.42657	.90446	.44229	.89687	.45787	.88902	45	11
7	16	.41098	.91164	.42683	.90433	.44255	.89674	.45813	.88888	44	[illegible]
7	17	.41125	.91152	.42709	.90421	.44281	.89662	.45839	.88875	43	10
8	18	.41151	.9114	.42736	.90408	.44307	.89649	.45865	.88862	42	10
8	19	.41178	.91128	.42762	.90396	.44333	.89636	.45891	.88848	41	10
9	20	.41204	.91116	.42788	.90383	.44359	.89623	.45917	.88835	40	9
9	21	.41231	.91104	.42815	.90371	.44385	.8961	.45942	.88822	39	9
10	22	.41257	.91092	.42841	.90358	.44411	.89597	45968	.88808	38	[illegible]
10	23	.41284	.9108	.42867	.90346	.44437	.89584	.45994	.88795	37	[illegible]
10	24	.4131	.91068	.42894	.90334	.44464	.89571	4602	.88782	36	[illegible]
11	25	.41337	.91056	.4292	.90321	.4449	.89558	.46046	.88768	35	[illegible]
11	26	.41363	.91044	.42946	.90309	.44516	.89545	.46072	.88755	34	[illegible]
12	27	.4139	.91032	.42972	.90296	.44542	.89532	46097	.88741	33	[illegible]
12	28	.41416	.9102	.42999	.90284	.44568	.89519	.46123	.88728	32	7
13	29	.41443	.91008	.43025	90271	.44594	.89506	.46149	.88715	31	7
13	30	.41469	.90996	.43051	.90259	.4462	.89493	.46175	.88701	30	7
13	31	.41496	.90984	.43077	.90246	.44646	.8948	46201	.88688	29	7
14	32	.41522	.90972	.43104	.90233	.44672	.89467	.46226	.88674	28	[illegible]
14	33	.41549	9096	.4313	.90221	.44698	.89454	.46252	.88661	27	[illegible]
15	34	.41575	.90948	.43156	.90208	.44724	.89441	.46278	.88647	26	[illegible]
15	35	.41602	.90936	.43182	.90196	.4475	.89428	.46304	.88634	25	[illegible]
16	36	.41628	.90924	.43209	.90183	.44776	.89415	.4633	.8862	24	[illegible]
16	37	.41655	.90911	.43235	.90171	.44802	.89402	.46355	.88607	23	5
16	38	.41681	.90899	.43261	90158	.44828	.89389	.46381	.88593	22	5
17	39	.41707	.90887	.43287	.90146	.44854	.89376	.46407	.8858	21	5
17	40	.41734	.90875	.43313	.90133	.4488	.89363	.46433	.88566	20	5
18	41	.4176	.90863	.4334	.9012	.44906	.8935	.46458	.88553	19	4
18	42	.41787	.90851	.43366	.90108	.44932	.89337	.46484	.88539	18	4
19	43	.41813	.90839	.43392	.90095	.44958	.89324	.4651	.88526	17	4
19	44	.4184	.90826	.43418	90082	.44984	.89311	.46536	.88512	16	4
20	45	.41866	.90814	.43445	.9007	.4501	.89298	.46561	.88499	15	[illegible]
20	46	.41892	.90802	.43471	.90057	.45036	.89285	.46587	.88485	14	[illegible]
20	47	.41919	.9079	.43497	.90045	.45062	.89272	.46613	.88472	13	[illegible]
21	48	.41945	.90778	.43523	.90032	.45088	.89259	.46639	.88458	12	[illegible]
21	49	.41972	.90766	.43549	.90019	.45114	.89245	.46664	.88445	11	[illegible]
22	50	.41998	.90753	.43575	.90007	4514	.89232	.4669	.88431	10	[illegible]
22	51	.42024	.90741	.43602	89994	.45166	.89219	.46716	.88417	9	[illegible]
23	52	.42051	.90729	.43628	.89981	.45192	.89206	.46742	.88404	8	[illegible]
23	53	.42077	.90717	.43654	.89968	45218	.89193	.46767	.8839	7	[illegible]
23	54	.42104	.90704	4368	.89956	.45243	.8918	.46793	.88377	6	[illegible]
24	55	.4213	.90692	.43706	.89943	.45269	89167	.46819	.88363	5	[illegible]
24	56	.42156	.9068	.43733	.8993	.45295	.89153	.46844	.88349	4	[illegible]
25	57	.42183	.90668	.43759	.89918	45321	.8914	.4687	.88336	3	[illegible]
25	58	.42209	.90655	.43785	.89905	.45347	.89127	.46896	.88322	2	[illegible]
26	59	.42235	.90643	.43811	.89892	.45373	.89114	46921	88308	1	[illegible]
26	60	.42262	.90631	.43837	.89879	.45399	.89101	.46947	88295	0	[illegible]
		N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	′	
		65°		64°		63°		62°			

′	28°		29°		30°		31°			Prop. parts.
	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.		14
0	.46947	.88295	.48481	.87462	.5	.86603	.51504	.85717	60	14
1	.46973	.88281	.48506	.87448	.50025	.86588	.51529	.85702	59	14
2	.46999	.88267	.48532	.87434	.5005	.86573	.51554	.85687	58	14
3	.47024	.88254	.48557	.8742	.50076	.86559	.51579	.85672	57	13
4	.4705	.8824	.48583	.87406	.50101	.86544	.51604	.85657	56	13
5	.47076	.88226	.48608	.87391	.50126	.8653	.51628	.85642	55	13
6	.47101	.88213	.48634	.87377	.50151	.86515	.51653	.85627	54	13
7	.47127	.88199	.48659	.87363	.50176	.86501	.51678	.85612	53	12
8	.47153	.88185	.48684	.87349	.50201	.86486	.51703	.85597	52	12
9	.47178	.88172	.4871	.87335	.50227	.86471	.51728	.85582	51	12
10	.47204	.88158	.48735	.87321	.50252	.86457	.51753	.85567	50	12
11	.47229	.88144	.48761	.87306	.50277	.86442	.51778	.85551	49	11
12	.47255	.8813	.48786	.87292	.50302	.86427	.51803	.85536	48	11
13	.47281	.88117	.48811	.87278	.50327	.86413	.51828	.85521	47	11
14	47306	.88103	.48837	.87264	.50352	.86398	.51852	.85506	46	11
15	.47332	.88089	.48862	.8725	.50377	.86384	.51877	.85491	45	11
16	.47358	.88075	.48888	.87235	.50403	.86369	.51902	.85476	44	10
17	.47383	.88062	.48913	.87221	.50428	.86354	.51927	.85461	43	10
18	.47409	.88048	.48938	.87207	.50453	.8634	.51952	.85446	42	10
19	.47434	.88034	.48964	.87193	.50478	.86325	.51977	.85431	41	10
20	.4746	.8802	.48989	.87178	.50503	.8631	.52002	.85416	40	9
21	.47486	.88006	.49014	.87164	.50528	.86295	.52026	.85401	39	9
22	.47511	.87993	.4904	.8715	.50553	.86281	.52051	.85385	38	9
23	.47537	.87979	.49065	.87136	.50578	.86266	.52076	.8537	37	9
24	.47562	.87965	.4909	.87121	.50603	.86251	.52101	.85355	36	8
25	.47588	.87951	.49116	.87107	.50628	.86237	.52126	.8534	35	8
26	.47614	.87937	.49141	.87093	.50654	.86222	.52151	.85325	34	8
27	.47639	.87923	.49166	.87079	.50679	.86207	.52175	.8531	33	8
28	.47665	.87909	.49192	.87064	.50704	.86192	.522	.85294	32	7
29	.4769	.87896	.49217	.8705	.50729	.86178	.52225	.85279	31	7
30	.47716	.87882	.49242	.87036	.50754	.86163	.5225	.85264	30	7
31	.47741	.87868	.49268	.87021	.50779	.86148	.52275	.85249	29	7
32	.47767	.87854	.49293	.87007	.50804	.86133	.52299	.85234	28	7
33	.47793	.8784	.49318	.86993	.50829	.86119	.52324	.85218	27	6
34	.47818	.87826	.49344	.86978	.50854	.86104	.52349	.85203	26	6
35	.47844	.87812	.49369	.86964	.50879	.86089	.52374	.85188	25	6
36	.47869	.87798	.49394	.86949	.50904	.86074	.52399	.85173	24	6
37	.47895	.87784	.49419	.86935	.50929	.86059	.52423	.85157	23	5
38	.4792	.8777	.49445	.86921	.50954	.86045	.52448	.85142	22	5
39	.47946	.87756	.4947	.86906	.50979	.8603	.52473	.85127	21	5
40	.47971	.87743	.49495	.86892	.51004	.86015	.52498	.85112	20	5
41	.47997	.87729	.49521	.86878	.51029	.86	.52522	.85096	19	4
42	.48022	.87715	.49546	.86863	.51054	.85985	.52547	.85081	18	4
43	.48048	.87701	.49571	.86849	.51079	.8597	.52572	.85066	17	4
44	.48073	.87687	.49596	.86834	.51104	.85956	.52597	.85051	16	4
45	.48099	.87673	.49622	.8682	.51129	.85941	.52621	.85035	15	4
46	.48124	.87659	.49647	.86805	.51154	.85926	.52646	.8502	14	3
47	.4815	.87645	.49672	.86791	.51179	.85911	.52671	.85005	13	3
48	.48175	.87631	.49697	.86777	.51204	.85896	.52696	.84989	12	3
49	.48201	.87617	.49723	.86762	.51229	.85881	.5272	.84974	11	3
50	.48226	.87603	.49748	.86748	.51254	.85866	.52745	.84959	10	[illegible]
51	.48252	.87589	.49773	.86733	.51279	.85851	.5277	.84943	9	
52	.48277	.87575	.49798	.86719	.51304	.85836	.52794	[illegible]	8	
53	.48303	.87561	.49824	.86704	.51329	.85821	.5281[illegible]			
54	.48328	.87546	.49849	.8669	.51354	.85806	.528[illegible]			
55	.48354	.87532	.49874	.86675	.51379	.85792	.52[illegible]			
56	.48379	.87518	.49899	.86661	.51404	.85777	.52[illegible]			
[illegible]	.48405	.87504	.49924	.86646	.51429	.85762	.52[illegible]			
	[illegible]	.8749	.4995	.86632	.51454	.85747	.52[illegible]			
		.87476	.49975	.86617	.51479	.85732	.52[illegible]			
		[illegible]	.5	.86603	.51504	.85717	.52[illegible]			
		ne.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos			
			60°		59°					

Prop. parts.	′	32°		33°		34°		35°		
23	′	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	
0	0	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	60
0	1	.53017	.84789	.54488	.83851	.55943	.82887	.57381	.81899	59
1	2	.53041	.84774	.54513	.83835	.55968	.82871	.57405	.81882	58
1	3	.53066	.84759	.54537	.83819	.55992	.82855	.57429	.81865	57
2	4	.53091	.84743	.54561	.83804	.56016	.82839	.57453	.81848	56
2	5	.53115	.84728	.54586	.83788	.5604	.82822	.57477	.81832	55
2	6	.5314	.84712	.5461	.83772	.56064	.82806	.57501	.81815	54
3	7	.53164	.84697	.54635	.83756	.56088	.8279	.57524	.81798	53
3	8	.53189	.84681	.54659	.8374	.56112	.82773	.57548	.81782	52
3	9	.53214	.84666	.54683	.83724	.56136	.82757	.57572	.81765	51
4	10	.53238	.8465	.54708	.83708	.5616	.82741	.57596	.81748	50
4	11	.53263	.84635	.54732	.83692	.56184	.82724	.57619	.81731	49
5	12	.53288	.84619	.54756	.83676	.56208	.82708	.57643	.81714	48
5	13	.53312	.84604	.54781	.8366	.56232	.82692	.57667	.81698	47
5	14	.53337	.84588	.54805	.83645	.56256	.82675	.57691	.81681	46
6	15	.53361	.84573	.54829	.83629	.5628	.82659	.57715	.81664	45
6	16	.53386	.84557	.54854	.83613	.56305	.82643	.57738	.81647	44
7	17	.53411	.84542	.54878	.83597	.56329	.82626	.57762	.81631	43
7	18	.53435	.84526	.54902	.83581	.56353	.8261	.57786	.81614	42
7	19	.5346	.84511	.54927	.83565	.56377	.82593	.5781	.81597	41
8	20	.53484	.84495	.54951	.83549	.56401	.82577	.57833	.8158	40
8	21	.53509	.8448	.54975	.83533	.56425	.82561	.57857	.81563	39
8	22	.53534	.84464	.54999	.83517	.56449	.82544	.57881	.81546	38
9	23	.53558	.84448	.55024	.83501	.56473	.82528	.57904	.8153	37
9	24	.53583	.84433	.55048	.83485	.56497	.82511	.57928	.81513	36
10	25	.53607	.84417	.55072	.83469	.56521	.82495	.57952	.81496	35
10	26	.53632	.84402	.55097	.83453	.56545	.82478	.57976	.81479	34
10	27	.53656	.84386	.55121	.83437	.56569	.82462	.57999	.81462	33
11	28	.53681	.8437	.55145	.83421	.56593	.82446	.58023	.81445	32
11	29	.53705	.84355	.55169	.83405	.56617	.82429	.58047	.81428	31
12	30	.5373	.84339	.55194	.83389	.56641	.82413	.5807	.81412	30
12	31	.53754	.84324	.55218	.83373	.56665	.82396	.58094	.81395	29
12	32	.53779	.84308	.55242	.83356	.56689	.8238	.58118	.81378	28
13	33	.53804	.84292	.55266	.8334	.56713	.82363	.58141	.81361	27
13	34	.53828	.84277	.55291	.83324	.56736	.82347	.58165	.81344	26
13	35	.53853	.84261	.55315	.83308	.5676	.8233	.58189	.81327	25
14	36	.53877	.84245	.55339	.83292	.56784	.82314	.58212	.8131	24
14	37	.53902	.8423	.55363	.83276	.56808	.82297	.58236	.81293	23
15	38	.53926	.84214	.55388	.8326	.56832	.82281	.5826	.81276	22
15	39	.53951	.84198	.55412	.83244	.56856	.82264	.58283	.81259	21
15	40	.53975	.84182	.55436	.83228	.5688	.82248	.58307	.81242	20
16	41	.54	.84167	.5546	.83212	.56904	.82231	.5833	.81225	19
16	42	.54024	.84151	.55484	.83195	.56928	.82214	.58354	.81208	18
16	43	.54049	.84135	.55509	.83179	.56952	.82198	.58378	.81191	17
17	44	.54073	.8412	.55533	.83163	.56976	.82181	.58401	.81174	16
17	45	.54097	.84104	.55557	.83147	.57	.82165	.58425	.81157	15
18	46	.54122	.84088	.55581	.83131	.57024	.82148	.58449	.8114	14
18	47	.54146	.84072	.55605	.83115	.57047	.82132	.58472	.81123	13
18	48	.54171	.84057	.5563	.83098	.57071	.82115	.58496	.81106	12
19	49	.54195	.84041	.55654	.83082	.57095	.82098	.58519	.81089	11
	50	.5422	.84025	.55678	.83066	.57119	.82082	.58543	.81072	10
	51	.54244	.84009	.55702	.8305	.57143	.82065	.58567	.81055	9
		.54269	.83994	.55726	.83034	.57167	.82048	.5859	.81038	8
		[illegible]	.83978	.5575	.83017	.57191	.82032	.58614	.81021	7
			[illegible]	.55775	.83001	.57215	.82015	.58637	.81004	6
			[illegible]	.55799	.82985	.57238	.81999	.58661	.80987	5
				.55823	.82969	.57262	.81982	.58684	.8097	4
				[illegible]	.82953	.57286	.81965	.58708	.80953	3
					[illegible]	.5731	.81949	.58731	.80936	2
						.57334	.81932	.58755	.80919	1
						.57358	.81915	.58779	.80902	0
						N. cos.	N. sine.	N. cos.	N. sine.	′
						55°		54°		

36°		37°		38°		39°			Prop. parts.
N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.		18
58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60	18
58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	59	18
58826	.80867	.60228	.79829	.61612	.78765	.62977	.77678	58	17
58849	.8085	.60251	.79811	.61635	.78747	.63	.7766	57	17
58873	.80833	.60274	.79793	.61658	.78729	.63022	.77641	56	17
58896	.80816	.60298	.79776	.61681	.78711	.63045	.77623	55	17
.5892	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54	16
.58943	.80782	.60344	.79741	.61726	.78676	.6309	.77586	53	16
.58967	.80765	.60367	.79723	.61749	.78658	.63113	.77568	52	16
.5899	.80748	.6039	.79706	.61772	.7864	.63135	.7755	51	15
.59014	.8073	.60414	.79688	.61795	.78622	.63158	.77531	50	15
.59037	.80713	.60437	.79671	.61818	.78604	.6318	.77513	49	15
.59061	.80696	.6046	.79653	.61841	.78586	.63203	.77494	48	14
.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47	14
.59108	.80662	.60506	.79618	.61887	.7855	.63248	.77458	46	14
.59131	.80644	.60529	.796	.61909	.78532	.63271	.77439	45	14
.59154	.80627	.60553	79583	61932	.78514	.63293	.77421	44	13
.59178	.8061	.60576	.79565	.61955	.78496	.63316	.77402	43	13
.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42	13
.59225	.80576	.60622	.7953	62001	.7846	.63361	.77366	41	12
.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40	12
.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39	12
.59295	.80524	.60691	.79477	.62069	.78405	.63428	.7731	38	11
.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37	11
.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36	11
.59365	.80472	.60761	.79424	.62138	.78351	63496	.77255	35	11
.59389	.80455	.60784	.79406	.6216	.78333	.63518	.77236	34	10
.59412	.80438	.60807	.79388	.62183	.78315	.6354	.77218	33	10
.59436	.8042	.6083	.79371	.62206	.78297	.63563	.77199	32	10
.59459	.80403	.60853	.79353	.62229	.78279	.63585	.77181	31	9
.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30	9
.59506	.80368	.60899	.79318	.62274	.78243	.6363	.77144	29	9
.59529	.80351	.60922	.793	.62297	.78225	.63653	.77125	28	8
.59552	.80334	.60945	.79282	.6232	.78206	.63675	.77107	27	8
.59576	.80316	.60968	.79264	62342	.78188	.63698	.77088	26	8
.59599	.80299	.60991	.79247	.62365	.7817	.6372	.7707	25	8
.59622	.80282	.61015	.79229	.62388	78152	.63742	.77051	24	7
.59646	.80264	.61038	.79211	.62411	.78134	.63765	.77033	23	7
.59669	.80247	.61061	.79193	.62433	78116	63787	.77014	22	7
.59693	.8023	.61084	.79176	.62456	.78098	6381	.76996	21	6
.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20	6
.59739	.80195	.6113	.7914	.62502	.78061	.63854	.76959	19	6
.59763	.80178	.61153	.79122	.62524	.78043	.63877	.7694	18	5
.59786	.8016	.61176	.79105	.62547	.78025	.63899	.76921	17	5
.59809	.80143	.61199	.79087	.6257	.78007	.63922	.76903	16	5
.59832	.80125	.61222	.79069	.62592	.77988	.63944	.76884	15	5
.59856	.80108	.61245	.79051	.62615	.7797	.63966	.76866	14	4
.59879	.80091	.61268	.79033	.62638	.77952	.63989	.76847	13	4
.59902	.80073	.61291	.79016	.6266	.77934	.64011	.76828	12	4
.59926	.80056	.61314	.78998	62683	.77916	.64033	.7681	11	3
.59949	.80038	.61337	.7898	.62706	.77897	.64056	.76791	10	3
.59972	.80021	.6136	.78962	.62728	.77879	.64078	.76772	9	3
.59995	.80003	.61383	.78944	.62751	.77861	.641	.76754	8	2
.60019	.79986	61406	.78926	.62774	.77843	.64123	.76735	7	2
.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6	2
.60065	.79951	.61451	.78891	.62819	.77806	.64167	.76698	5	2
.60089	.79934	.61474	.78873	62842	.77788	.6419	.76679	4	1
.60112	.79916	.61497	.78855	.62864	.77769	64212	.76661	3	1
.60135	.79899	.6152	.78837	.62887	.77751	.64234	.76642	2	1
.60158	.79881	.61543	78819	.62909	.77733	.64256	.76623	1	0
.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	0	0
N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	N. cos.	N. sine.	′	
53°		52°		51°		50°			

[illegible]	′	40° N. sine.	40° N. cos.	41° N. sine.	41° N. cos.	42° N. sine.	42° N. cos.	43° N. sine.	43° N. cos.	
0	0	[illegible]	[illegible]	.65606	75471	[illegible]	[illegible]	[illegible]	[illegible]	60
0	1	[illegible]	[illegible]	[illegible]	.75452	[illegible]	[illegible]	[illegible]	[illegible]	59
1	2	[illegible]	[illegible]	[illegible]	.75433	[illegible]	[illegible]	[illegible]	[illegible]	58
1	3	[illegible]	[illegible]	[illegible]	.75414	[illegible]	[illegible]	[illegible]	[illegible]	57
1	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56
2	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55
2	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54
3	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53
3	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52
3	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51
4	10	[illegible]	[illegible]	.65825	[illegible]	[illegible]	.7412	[illegible]	[illegible]	50
4	11	.64524	[illegible]	.65847	.75261	.67151	.741	[illegible]	[illegible]	49
4	12	[illegible]	[illegible]	.65869	75241	.67172	[illegible]	[illegible]	[illegible]	48
5	13	[illegible]	[illegible]	.65891	75222	[illegible]	[illegible]	[illegible]	[illegible]	47
5	14	[illegible]	.76342	.65913	[illegible]	.67215	[illegible]	[illegible]	[illegible]	46
5	15	[illegible]	.76323	.65935	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45
6	16	[illegible]	[illegible]	[illegible]	.75165	[illegible]	[illegible]	[illegible]	.72817	44
6	17	[illegible]	[illegible]	[illegible]	.75146	[illegible]	[illegible]	[illegible]	.72797	43
7	18	[illegible]	[illegible]	.66	.75126	.67301	[illegible]	[illegible]	72777	42
7	19	[illegible]	[illegible]	.66022	[illegible]	.67323	[illegible]	[illegible]	.72757	41
7	20	[illegible]	[illegible]	.66044	[illegible]	.67344	.73924	.68624	.72737	40
8	21	[illegible]	.7621	.66066	.75069	[illegible]	.73904	.68645	.72717	39
8	22	[illegible]	.76192	.66088	.7505	[illegible]	.73885	.68666	.72697	38
8	23	[illegible]	.76173	.66109	.7503	.67409	.73865	.68688	72677	37
9	24	[illegible]	.76154	.66131	.75011	.6743	73846	.68709	.72657	36
9	25	[illegible]	.76135	.66153	.74992	.67452	.73826	.6873	71637	35
10	26	[illegible]	.76116	.66175	.74973	.67473	.73806	.68751	.72617	34
10	27	[illegible]	.76097	.66197	.74953	.67495	.73787	.68772	.72597	33
10	28	[illegible]	76078	.66218	.74934	.67516	.73767	.68793	.72577	32
11	29	[illegible]	76059	.6624	.74915	.67538	.73747	.68814	.72557	31
11	30	[illegible]	.76041	.66262	.74896	.67559	.73728	.68835	.72537	30
11	31	[illegible]	.76022	.66284	.74876	.6758	.73708	.68857	.72517	29
12	32	[illegible]	.76003	.66306	.74857	.67602	.73688	.68878	.72497	28
12	33	.65011	.75984	.66327	.74838	.67623	.73669	.68899	.72477	27
12	34	.65033	.75965	.66349	.74818	.67645	.73649	.6892	.72457	26
13	35	.65055	.75946	.66371	.74799	.67666	.73629	.68941	.72437	25
13	36	.65077	.75927	.66393	.7478	.67688	.7361	.68962	.72417	24
14	37	.651	.75908	.66414	.7476	.67709	.7359	.68983	.72397	23
14	38	.65122	.75889	.66436	74741	.6773	.7357	.69004	.72377	22
14	39	.65144	.7587	.66458	.74722	.67752	.73551	.69025	.72357	21
15	40	.65166	.75851	.6648	.74703	.67773	.73531	.69046	.72337	20
15	41	.65188	.75832	.66501	.74683	.67795	.73511	.69067	.72317	19
15	42	.6521	.75813	.66523	.74664	.67816	.73491	.69088	.72297	18
16	43	.65232	.75794	.66545	.74644	.67837	.73472	.69109	.72277	17
16	44	.65254	.75775	.66566	.74625	.67859	.73452	.6913	.72257	16
17	45	.65276	.75756	.66588	.74606	.6788	.73432	.69151	.72236	15
17	46	.65298	.75738	.6661	.74586	.67901	.73413	.69172	.72216	14
17	47	.6532	.75719	.66632	.74567	.67923	.73393	.69193	.72196	13
18	48	.65342	.757	.66653	.74548	.67944	.73373	.69214	.72176	12
18	49	.65364	.7568	.66675	.74528	.67965	.73353	.69235	.72156	11
18	50	.65386	.75661	.66697	.74509	.67987	.73333	.69256	.72136	10
19	51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	9
19	52	.6543	.75623	.6674	7447	.68029	.73294	.69298	.72095	8
19	53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	72075	7
[illegible]	[illegible]	[illegible]	.75585	.66783	.74431	.68072	.73254	.6934	.72055	6
[illegible]	[illegible]	[illegible]	.75566	.66805	.74412	.68093	.73234	.69361	.72035	5
[illegible]	[illegible]	[illegible]	[illegible]	.66827	.74392	.68115	.73215	.69382	.72015	4
[illegible]	[illegible]	[illegible]	[illegible]	.66848	.74373	.68136	.73195	69403	.71995	3
[illegible]	[illegible]	[illegible]	[illegible]	.6687	.74353	68157	.73175	.69424	.71974	2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.74334	68179	.73155	.69445	.71954	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.74314	.682	.73135	69466	.71934	0
		[illegible]	[illegible]	[illegible]	[illegible]	N. cos.	N. sine.	N. cos.	N. sine.	
								46°		

	44°			Prop. parts.	Prop. parts.		44°			Prop. parts.
′	N. sine.	N. cos.		19	22	′	N. sine.	N. cos.		9
0	.69466	.71934	60	19	11	31	.70112	.71305	29	9
1	.69487	.71914	59	19	12	32	.70132	.71284	28	9
2	.69508	.71894	58	18	12	33	.70153	.71264	27	9
3	.69529	.71873	57	18	12	34	.70174	.71243	26	8
4	.69549	.71853	56	18	13	35	.70195	.71223	25	8
5	.6957	.71833	55	17	13	36	.70215	.71203	24	8
6	.69591	.71813	54	17	14	37	.70236	.71182	23	7
7	.69612	.71792	53	17	14	38	.70257	.71162	22	7
8	.69633	.71772	52	16	14	39	.70277	.71141	21	7
9	.69654	.71752	51	16	15	40	.70298	.71121	20	6
10	.69675	.71732	50	16	15	41	.70319	.711	19	6
11	.69696	.71711	49	16	15	42	.70339	.7108	18	6
12	.69717	.71691	48	15	16	43	.7036	.71059	17	5
13	.69737	.71671	47	15	16	44	.70381	.71039	16	5
14	.69758	.7165	46	15	17	45	.70401	.71019	15	5
15	.69779	.7163	45	14	17	46	.70422	.70998	14	4
16	.698	.7161	44	14	17	47	.70443	.70978	13	4
17	.69821	.7159	43	14	18	48	.70463	.70957	12	4
18	.69842	.71569	42	13	18	49	.70484	.70937	11	3
19	.69862	.71549	41	13	18	50	.70505	.70916	10	3
20	.69883	.71529	40	13	19	51	.70525	.70896	9	3
21	.69904	.71508	39	12	19	52	.70546	.70875	8	3
22	.69925	.71488	38	12	19	53	.70567	.70855	7	2
23	.69946	.71468	37	12	20	54	.70587	.70834	6	2
24	.69966	.71447	36	11	20	55	.70608	.70813	5	2
25	.69987	.71427	35	11	21	56	.70628	.70793	4	1
26	.70008	.71407	34	11	21	57	.70649	.70772	3	1
27	.70029	.71386	33	10	21	58	.7067	.70752	2	1
28	.70049	.71366	32	10	22	59	.7069	.70731	1	0
29	.7007	.71345	31	10	22	60	.70711	.70711	0	0
30	.70091	.71325	30	10						
	N. cos.	N. sine.	′				N. cos.	N. sine.	′	
	45°						45°			

Preceding Table contains Natural Sine and Cosine for every minute the Quadrant to Radius 1.

If Degrees are taken at head of columns, Minutes, Sine, and Cosine must taken from head also; and if they are taken at foot of column, Minutes, ., must be taken from foot also.

LLUSTRATION.—.3173 is sine of 18° 30′, and cosine of 71° 30′.

To Compute Sine or Cosine for Seconds.

***When Angle is less than* 45°. RULE.—Ascertain sine or cosine of angle degrees and minutes from Table; take difference between it and sine cosine of angle next below it. Look for this difference or remainder Sine is required, at head of column of *Proportional Parts*, on left side if *Cosine* is required, at head of column on right side; and in the spective columns, opposite to number of seconds of angle in column, is mber or correction in seconds to be added to Sine, or subtracted from sine of angle.**

ILLUSTRATION 1.—What is sine of 8° 9′ 10″?

Sine of 8° 9′, per Table = .141 77;
Sine of 8° 10′, " = .142 05; } **.000 28 *difference***

In left side column of proportional parts*, under 28, and opposit *10′*, *which, being added to* .141 77 = .141 82 *Sine.

Some instances will give a unit too much, but this, in general, is c.

2.—What is cosine of $8^\circ\ 9'\ 10''$?

Cosine of $8^\circ\ 9'$, per Table $= .98990$; Cosine of $8^\circ\ 10'$, " $= .98986$; $\}$ .00004 *difference.*

In right-side column of *proportional parts*, under 4, and opposite to $10'$, is 1, the correction for $10'$, which, being subtracted from $.98990 = .98989$ *cosine.*

When Angle exceeds 45°. RULE.—Ascertain sine or cosine for angle in degrees and minutes from Table, taking degrees at the foot of it; then take difference between it and sine or cosine of angle next above it. Look for remainder, if *Sine* is required, at head of column of *Proportional Parts*, on right side; and if *Cosine* is required, at head of column on left side; and in these respective columns, opposite to seconds of angle, is number or correction in seconds to be added to Sine, or subtracted from Cosine of angle.

ILLUSTRATION.—What is the Sine and Cosine of $81^\circ\ 50'\ 50''$?

Sine of $81^\circ\ 50'$, per Table $= .98986$; Sine of $81^\circ\ 51'$, " $= .9899$; $\}$ .00004 *difference.*

In right-side column of *proportional parts*, and opposite to $50'$, is 3, which, added to $.98986 = .98989$ *Sine.*

Cosine of $81^\circ\ 50'$, per Table $= .14205$; Cosine of $81^\circ\ 51'$, " $= .14177$; $\}$ .00025 *difference.*

In left-side column of *proportional parts*, and opposite to $50'$, is 24, which, subtracted from $.14205 = .14181$ *Cosine.*

To Ascertain or Compute Number of Degrees, Minutes, and Seconds of a given Sine or Cosine.

When Sine is given. RULE.—If given *sine* is in Table, the degrees of it will be at top or bottom of page, and minutes in marginal column, at left or right side, according as sine corresponds to an angle less or greater than 45°.

If given sine is not in Table, take sine in Table which is next *less* than the one for which degrees, etc., are required, and note degrees, etc., for it. Subtract this sine from next *greater* tabular sine, and also from given sine.

Then, as tabular difference is to difference between given sine and tabular sine, so is 60 seconds to seconds for sine given.

EXAMPLE.—What are the degrees, minutes, and seconds for sine of .75?

Next less sine is .74992, *arc for which is* $48^\circ\ 35'$. Next greater sine is .75011, *difference between which and next less is* $.75011 - .74992 = .00019$. *Difference between less tabular sine and one given is* $.75 - .74992 = 8$.

Then $19 : 8 :: 60 : 25+$, which, added to $48^\circ\ 35' = 48^\circ\ 35'\ 25''$.

When Cosine is given. RULE.—If given *cosine* is found in Table, degrees of it will be found as in manner specified when *sine* is given.

If given cosine is not in Table, take cosine in Table which is next *greater* than one for which degrees, etc., are required, and note degrees, etc., for it. Subtract this cosine from next *less* tabular cosine, and also from given cosine.

Then, as tabular difference is to difference between given cosine and tabular cosine, so is 60 seconds to seconds for cosine given.

EXAMPLE.—What are the degrees, minutes, and seconds for cosine of .75?

Next greater cosine is .75011, *arc for which is* $41^\circ\ 24'$. Next less cosine is .74992, *difference between which and next greater is* $.75011 - .74992 = .00019$. *Difference between greater tabular cosine and one given is* $.75011 - .75000 = 11$.

Then $19 : 11 :: 60 : 35-$, which, added to $41^\circ\ 24' = 41^\circ\ 24'\ 35''$.

[illegible]mpute Versed Sine of an Angle.

R[illegible] angle from 1.

[illegible] is the versed sine of $21^\circ\ 30'$?

[illegible] $30'$ is .93042, which, $-1 = .06958$ versed sine.

[illegible]ute Co-versed Sine of an Angle.

[illegible]

[illegible] versed sine.

Natural Secants and Co-secants.

0°		1°		2°		3°		
NT.	Co-secant.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	′
	Infinite.	1.0001	57.299	1.0006	28.654	1.0014	19.107	60
	3437.7	.0001	6.359	.0006	8.417	.0014	9.002	59
	1718.9	.0002	5.45	.0006	8.184	.0014	8.897	58
	145.9	.0002	4.57	.0006	7.955	.0014	8.794	57
	859.44	.0002	3.718	.0006	7.73	.0014	8.692	56
	687.55	1.0002	52.891	1.0007	27.508	1.0014	18.591	55
	572.96	.0002	2.09	.0007	7.29	.0015	8.491	54
	491.11	.0002	1.313	.0007	7.075	.0015	8.393	53
	29.72	.0002	0.558	.0007	6.864	.0015	8.295	52
	381.97	.0002	49.826	.0007	6.655	.0015	8.198	51
	343.77	1.0002	49.114	1.0007	26.45	1.0015	18.103	50
	12.52	.0002	8.422	.0007	6.249	.0015	8.008	49
	286.48	.0002	7.75	.0007	6.05	.0016	7.914	48
	64.44	.0002	7.096	.0007	5.854	.0016	7.821	47
	45.55	0002	6.46	.0008	5.661	.0016	7.73	46
	229:18	1.0002	45.84	1.0008	25.471	1.0016	17.639	45
	14.86	.0002	5.237	.0008	5.284	.0016	7.549	44
	02.22	.0002	4.65	.0008	5.1	.0016	7.46	43
	190.99	.0002	4.077	.0008	4.918	.0017	7.372	42
	80.73	.0003	3.52	.0008	4.739	.0017	7.285	41
	171.89	1.0003	42.976	1.0008	24.562	1.0017	17.198	40
	63.7	.0003	2.445	.0008	4.358	.0017	7.113	39
	56.26	.0003	1.928	.0008	4.216	.0017	7.028	38
	49.47	.0003	1.423	.0009	4.047	.0017	6.944	37
	43.24	.0003	40.93	.0009	3.88	.0018	6.861	36
	137.51	1.0003	40.448	1.0009	23.716	1.0018	16.779	35
	32.22	.0003	39.978	.0009	3.553	.0018	6.698	34
	27.32	.0003	9.518	.0009	3.393	.0018	6.617	33
	22.78	.0003	9.069	.0009	3.235	.0018	6.538	32
	18.54	.0003	8.631	.0009	3.079	.0018	6.459	31
	114.59	1.0003	38.201	1.0009	22.925	1.0019	16.38	30
	10.9	.0003	7.782	.001	2.774	.0019	6.303	29
	07.43	.0003	7.371	.001	2.624	.0019	6.226	28
	04.17	.0004	6.969	.001	2.476	.0019	6.15	27
	01.11	.0004	6.576	.001	2.33	.0019	6.075	26
	98.223	1.0004	36.191	1.001	22.186	1.0019	16	25
	5.495	.0004	5.814	.001	2.044	.002	5.926	24
	2.914	.0004	5.445	.001	1.904	.002	5.853	23
001	2.469	.0004	5.084	.001	1.765	.002	5.78	22
001	88.149	.0004	4.729	.0011	1.629	.002	5.708	21
001	85.946	1.0004	34.382	1.0011	21.494	1.002	15.637	20
001	3.849	.0004	4.042	.0011	1.36	.0021	5.566	19
001	1.853	.0004	3.708	.0011	1.228	.0021	5.496	18
001	79 95	.0004	3.381	.0011	1.098	.0021	5.427	17
001	8.133	.0004	3.06	.0011	20.97	.0021	5.358	16
001	76.396	1.0005	32.745	1.0011	20.843	1.0021	15.29	[illegible]
001	4.736	.0005	2.437	.0012	0.717	.0022	5.222	
001	3.146	.0005	2.134	.0012	0.593	.0022	5.155	
001	1.622	.0005	1.836	.0012	0.471	.0022	5.089	
001	1.16	.0005	1.544	.0012	0.35	.0022	5.023	
001	68.757	1.0005	31.257	1.0012	20.23	1.0022	14.958	
001	7.409	.0005	30.976	.0012	0.112	.0023	4.893	
001	6.113	.0005	0.699	.0012	19.995	.0023	4.829	
001	4.866	.0005	0.428	.0013	9.88		4.765	
001	3.664	0005	0.161	.0013	9.766			
001	62.507	1.0005	29.899	1.0013	19.653			
001	1.391	.0006	9.641	.0013	9.541			
001	1.314	.0006	9.388	.0013	9.431			
001	59.274	.0006	9.139	.0013	9.322			
001	8.27	.0006	8.894	0013	9.214			
001	57.299	1.0006	28.654	1.0014	19.107			
'T.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.			
89°		88°		87°				

	4°		5°		6°		7°	
′	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.
0	1.0024	14.335	1.0038	11.474	1.0055	9.5668	1.0075	8.2055
1	.0025	4.276	.0038	1.436	.0055	.5404	.0075	.1861
2	.0025	4.217	.0039	1.398	.0056	.5141	.0076	.1668
3	.0025	4.159	.0039	1.36	.0056	.488	.0076	.1476
4	.0025	4.101	.0039	1.323	.0056	.462	.0076	.1285
5	1.0025	14.043	1.0039	11.286	1.0057	9.4362	1.0077	8.1094
6	.0026	3.986	.004	1.249	.0057	.4105	.0077	.0905
7	.0026	3.93	.004	1.213	.0057	.385	.0078	.0717
8	.0026	3.874	.004	1.176	.0057	.3596	.0078	.0529
9	.0026	3.818	.004	1.14	.0058	.3343	.0078	.0342
10	1.0026	13.763	1.0041	11.104	1.0058	9.3092	1.0079	8.0156
11	.0027	3.708	.0041	1.069	.0058	.2842	.0079	7.9971
12	.0027	3.654	.0041	1.033	.0059	.2593	.0079	.9787
13	.0027	3.6	.0041	0.988	.0059	.2346	.008	.9604
14	.0027	3.547	.0042	0.963	.0059	.21	.008	.9421
15	1.0027	13.494	1.0042	10.929	1.006	9.1855	1.008	7.924
16	.0028	3.441	.0042	0.894	.006	.1612	.0081	.9059
17	.0028	3.389	.0043	0.86	.006	.137	.0081	.8879
18	.0028	3.337	.0043	0.826	.0061	.1129	.0082	.87
19	.0028	3.286	.0043	0.792	.0061	.089	.0082	.8522
20	1.0029	13.235	1.0043	10.758	1.0061	9.0651	1.0082	7.8344
21	.0029	3.184	.0044	0.725	.0062	.0414	.0083	.8168
22	.0029	3.134	.0044	0.692	.0062	.0179	.0083	.7992
23	.0029	3.084	.0044	0.659	.0062	8.9944	.0084	.7817
24	.0029	3.034	.0044	0.626	.0063	.9711	.0084	.7642
25	1.003	12.985	1.0045	10.593	1.0063	8.9479	1.0084	7.7469
26	.003	2.937	.0045	0.561	.0063	.9248	.0085	.7296
27	.003	2.888	.0045	0.529	.0064	.9018	.0085	.7124
28	.003	2.84	.0046	0.497	.0064	.879	.0085	.6953
29	.0031	2.793	.0046	0.465	.0064	.8563	.0086	.6783
30	1.0031	12.745	1.0046	10.433	1.0065	8.8337	1.0086	7.6613
31	.0031	2.698	.0046	0.402	.0065	.8112	.0087	.6444
32	.0031	2.652	.0047	0.371	.0065	.7888	.0087	.6276
33	.0032	2.606	.0047	0.34	.0066	.7665	.0087	.6108
34	.0032	2.56	.0047	0.309	.0066	.7444	.0088	.5942
35	1.0032	12.514	1.0048	10.278	1.0066	8.7223	1.0088	7.5776
36	.0032	2.469	.0048	0.248	.0067	.7004	.0089	.5611
37	.0032	2.424	.0048	0.217	.0067	.6786	.0089	.5446
38	.0033	2.379	.0048	0.187	.0067	.6569	.0089	.5282
39	.0033	2.335	.0049	0.157	.0068	.6353	.009	.5119
40	1.0033	12.291	1.0049	10.127	1.0068	8.6138	1.009	7.4957
41	.0033	2.248	.0049	0.098	.0068	.5924	.009	.4795
42	.0034	2.204	.005	0.068	.0069	.5711	.0091	.4634
43	.0034	2.161	.005	0.039	.0069	.5499	.0091	.4474
44	.0034	2.118	.005	0.01	.0069	.5289	.0092	.4315
45	1.0034	12.076	1.005	9.9812	1.007	8.5079	1.0092	7.4156
46	.0035	2.034	.0051	.9525	.007	.4871	.0092	.3998
47	.0035	1.992	.0051	.9239	.007	.4663	.0093	.384
48	.0035	1.95	.0051	.8955	.0071	.4457	.0093	.3683
49	.0035	1.909	.0052	.8672	.0071	.4251	.0094	.3527
50	1.0036	11.868	1.0052	9.8391	1.0071	8.4046	1.0094	7.3372
51	.0036	1.828	.0052	.8112	.0072	.3843	.0094	.3217
52	.0036	1.787	.0053	.7834	.0072	.3640	.0095	.3063
53	.0036	1.747	.0053	.7558	.0073	.3439	.0095	.2909
54	.0037	1.707	.0053	.7283	.0073	.3238	.0096	.2757
55	1.0037	11.668	1.0053	9.701	1.0073	8.3039	1.0096	7.2604
56	.0037	1.628	.0054	.6739	.0074	.2840	.0097	.2453
57	.0037	1.589	.0054	.6469	.0074	.2642	.0097	.2302
58	.0038	1.55	.0054	.62	.0074	.2446	.0097	.2152
59	.0038	1.512	.0055	.5933	.0075	.225	.0098	.2002
60	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	.0098	7.1853
′	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.
	85°		84°		83°		82°	

8°	9°		10°		11°		
Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	′
7.1853	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	60
.1704	.0125	.3807	.0155	.7493	.0188	.233	59
.1557	.0125	.369	.0155	.7398	.0188	.2252	58
.1409	.0126	.3574	.0156	.7304	.0189	.2174	57
.1263	.0126	.3458	.0156	.721	.0189	.2097	56
7.1117	1.0127	6.3343	1.0157	5.7117	1.019	5.2019	55
.0972	.0127	.3228	.0157	.7023	.0191	.1942	54
.0827	.0128	.3113	.0158	.693	.0191	.1865	53
.0683	.0128	.2999	.0158	.6838	.0192	.1788	52
.0539	.0129	.2885	.0159	.6745	.0192	.1712	51
7.0396	1.0129	6.2772	1.0159	5.6653	1.0193	5.1636	50
.0254	.013	.2659	.016	.6561	.0193	.156	49
.0112	.013	.2546	.016	.647	.0194	.1484	48
6.9971	.0131	.2434	.0161	.6379	.0195	.1409	47
.983	.0131	.2322	.0162	.6288	.0195	.1333	46
6.969	1.0132	6.2211	1.0162	5.6197	1.0196	5.1258	45
.955	.0132	.21	.0163	.6107	.0196	.1183	44
.9411	.0133	.199	.0163	.6017	.0197	.1109	43
.9273	.0133	.188	.0164	.5928	.0198	.1034	42
.9135	.0134	.177	.0164	.5838	.0198	.096	41
6.8998	1.0134	6.1661	1.0165	5.5749	1.0199	5.0886	40
.8861	.0135	.1552	.0165	.566	.0199	.0812	39
.8725	.0135	.1443	.0166	.5572	.02	.0739	38
.8589	.0136	.1335	.0166	.5484	.0201	.0666	37
.8454	.0136	.1227	.0167	.5396	.0201	.0593	36
6.832	1.0136	6.112	1.0167	5.5308	1.0202	5.052	35
.8185	.0137	.1013	.0168	.5221	.0202	.0447	34
.8052	.0137	.0906	.0169	.5134	.0203	.0375	33
.7919	.0138	.08	.0169	.5047	.0204	.0302	32
.7787	.0138	.0694	.017	.496	.0204	.023	31
6.7655	1.0139	6.0588	1.017	5.4874	1.0205	5.0158	30
.7523	.0139	.0483	.0171	.4788	.0205	.0087	29
.7392	.014	.0379	.0171	.4702	.0206	.0015	28
.7262	.014	.0274	.0172	.4617	.0207	4.9944	27
.7132	.0141	.017	.0172	.4532	.0207	.9873	26
6.7003	1.0141	6.0066	1.0173	5.4447	1.0208	4.9802	25
.6874	.0142	5.9963	.0174	.4362	.0208	.9732	24
.6745	.0142	.986	.0174	.4278	.0209	.9661	23
.6617	.0143	.9758	.0175	.4194	.021	.9591	22
.649	.0143	.9655	.0175	.411	.021	.9521	21
6.6363	1.0144	5.9554	1.0176	5.4026	1.0211	4.9452	20
.6237	.0144	.9452	.0176	.3943	.0211	.9382	19
.6111	.0145	.9351	.0177	.386	.0212	.9313	18
.5985	.0145	.925	.0177	.3777	.0213	.9243	17
.586	.0146	.915	.0178	.3695	.0213	.9175	16
6.5736	1.0146	5.9049	1.0179	5.3612	1.0214	4.9106	15
.5612	.0147	.895	.0179	.353	.0215	.9037	14
.5488	.0147	.885	.018	.3449	.0215	.8969	13
.5365	.0148	.8751	.018	.3367	.0216	.8901	12
.5243	.0148	.8652	.0181	.3286	.0216	.8833	11
6.5121	1.0149	5.8554	1.0181	5.3205	1.0217	4.8765	10
.4999	.015	.8456	.0182	.3124	.0218	.8697	9
.4878	.015	.8358	.0182	.3044	.0218	.863	8
.4757	.0151	.8261	.0183	.2963	.0219	.8563	7
.4637	.0151	.8163	.0184	.2883	.022	.8496	6
6.4517	1.0152	5.8067	1.0184	5.2803	1.022	4.8429	5
.4398	.0152	.797	.0185	.2724	.0221	.8362	4
.4279	.0153	.7874	.0185	.2645	.0221	.8296	3
.416	.0153	.7778	.0186	.2566	.0222	.8229	2
.4042	.0154	.7683	.0186	.2487	.0223	.8163	1
6.3924	1.0154	5.7588	1.0187	5.2408	1.0223	4.8097	0
Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	′
81°	80°		79°		78°		

′	12° Secant.	12° Co-sec't.	13° Secant.	13° Co-sec't.	14° Secant.	14° Co-sec't.	15° Secant.	15° Co-sec't.	′
0	1.0223	4.8097	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	60
1	.0224	.8032	.0264	.4398	.0307	.1287	.0353	.8595	59
2	.0225	.7966	.0264	.4342	.0308	.1239	.0354	.8553	58
3	.0225	.7901	.0265	.4287	.0308	.1191	.0355	.8512	57
4	.0226	.7835	.0266	.4231	.0309	.1144	.0356	.847	56
5	1.0226	4.777	1.0266	4.4176	1.031	4.1096	1.0357	3.8428	55
6	.0227	.7706	.0267	.4121	.0311	.1048	.0358	.8387	54
7	.0228	.7641	.0268	.4065	.0311	.1001	.0358	.8346	53
8	.0228	.7576	.0268	.4011	.0312	.0953	.0359	.8304	52
9	.0229	.7512	.0269	.3956	.0313	.0906	.036	.8263	51
10	1.023	4.7448	1.027	4.3901	1.0314	4.0859	1.0361	3.8222	50
11	.023	.7384	.0271	.3847	.0314	.0812	.0362	.8181	49
12	.0231	.732	.0271	.3792	.0315	.0765	.0362	.814	48
13	.0232	.7257	.0272	.3738	.0316	.0718	.0363	.81	47
14	.0232	.7193	.0273	.3684	.0317	.0672	.0364	.8059	46
15	1.0233	4.713	1.0273	4.363	1.0317	4.0625	1.0365	3.8018	45
16	.0234	.7067	.0274	.3576	.0318	.0579	.0366	.7978	44
17	.0234	.7004	.0275	.3522	.0319	.0532	.0367	.7937	43
18	.0235	.6942	.0276	.3469	.032	.0486	.0367	.7897	42
19	.0235	.6879	.0276	.3415	.032	.044	.0368	.7857	41
20	1.0236	4.6817	1.0277	4.3362	1.0321	4.0394	1.0369	3.7816	40
21	.0237	.6754	.0278	.3309	.0322	.0348	.037	.7776	39
22	.0237	.6692	.0278	.3256	.0323	.0302	.0371	.7736	38
23	.0238	.6631	.0279	.3203	.0323	.0256	.0371	.7697	37
24	.0239	.6569	.028	.315	.0324	.0211	.0372	.7657	36
25	1.0239	4.6507	1.028	4.3098	1.0325	4.0165	1.0373	3.7617	35
26	.024	.6446	.0281	.3045	.0326	.012	.0374	.7577	34
27	.0241	.6385	.0282	.2993	.0327	.0074	.0375	.7538	33
28	.0241	.6324	.0283	.2941	.0327	.0029	.0376	.7498	32
29	.0242	.6263	.0283	.2888	.0328	3.9984	.0376	.7459	31
30	1.0243	4.6202	1.0284	4.2836	1.0329	3.9939	1.0377	3.742	30
31	.0243	6142	0285	.2785	.033	.9894	.0378	.738	29
32	.0244	6081	.0285	.2733	.033	.985	.0379	.7341	28
33	.0245	.6021	.0286	.2681	.0331	.9805	.038	.7302	27
34	.0245	.5961	.0287	.263	.0332	.976	.0381	.7263	26
35	1.0246	4.5901	1.0288	4.2579	1.0333	3.9716	1.0382	3.7224	25
36	.0247	.5841	.0288	.2527	.0334	.9672	.0382	.7186	24
37	.0247	.5782	.0289	.2476	.0334	.9627	.0383	.7147	23
38	.0248	.5722	.029	.2425	.0335	.9583	.0384	.7108	22
39	.0249	.5663	.0291	.2375	.0336	.9539	.0385	.707	21
40	1.0249	4.5604	1.0291	4.2324	1.0337	3.9495	1.0386	3.7031	20
41	.025	.5545	.0292	.2273	.0338	.9451	.0387	.6993	19
42	.0251	.5486	.0293	.2223	.0338	.9408	.0387	.6955	18
43	.0251	.5428	.0293	.2173	.0339	.9364	.0388	.6917	17
44	.0252	.5369	.0294	.2122	.034	.932	.0389	.6878	16
45	1.0253	4.5311	1.0295	4.2072	1.0341	3.9277	1.039	3.684	15
46	.0253	.5253	.0296	.2022	.0341	.9234	.0391	.6802	14
47	.0254	.5195	.0296	.1972	.0342	.919	.0392	.6765	13
48	.0255	.5137	.0297	.1923	.0343	.9147	.0393	.6727	12
49	.0255	.5079	.0298	.1873	.0344	.9104	.0393	.6689	11
50	1.0256	4.5021	1.0299	4.1824	1.0345	3.9061	1.0394	3.6651	10
51	.0257	.4964	.0299	.1774	.0345	.9018	.0395	.6614	9
52	.0257	.4907	.03	.1725	.0346	.8976	.0396	.6576	8
53	.0258	.485	.0301	.1676	.0347	.8933	.0397	.6539	7
54	.0259	.4793	0302	.1627	.0348	.899	.0398	.6502	6
55	1.026	4.4736	1.0302	4.1578	1.0349	3.8848	1.0399	3.6464	5
56	.026	.4679	.0303	.1529	.0349	.8805	.0399	.6427	4
57	.0261	.4623	.0304	.1481	.035	.8763	.04	.639	3
58	.0262	.4566	.0305	.1432	.0351	.8721	.0401	.6353	2
59	.0262	.451	.0305	.1384	.0352	.8679	.0402	.6316	1
60	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	1.0403	3.6279	0
′	Co-sec't. 77°	Secant. 77°	Co-sec't. 76°	Secant. 76°	Co-sec't. 75°	Secant. 75°	Co-sec't. 74°	Secant. 74°	′

16°	17°		18°		19°		
Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	′
3.6279	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	60
.6243	.0458	.417	.0516	.2332	.0577	.069	59
.6206	.0459	.4138	.0517	.2303	.0578	.0664	58
.6169	.046	.4106	.0518	.2274	.0579	.0638	57
.6133	.0461	.4073	.0519	.2245	.058	.0612	56
3.6096	1.0461	3.4041	1.052	3.2216	1.0581	3.0586	55
.606	.0462	.4009	.0521	.2188	.0582	.0561	54
.6024	.0463	.3977	.0522	.2159	.0584	.0535	53
.5987	.0464	.3945	.0523	.2131	.0585	.0509	52
.5951	.0465	.3913	.0524	.2102	.0586	.0484	51
3.5915	1.0466	3.3881	1.0525	3.2074	1.0587	3.0458	50
.5879	.0467	.3849	.0526	.2045	.0588	.0433	49
.5843	.0468	.3817	.0527	.2017	.0589	.0407	48
.5807	.0469	.3785	.0528	.1989	.059	.0382	47
.5772	.047	.3754	.0529	.196	.0591	.0357	46
3.5736	1.0471	3.3722	1.053	3.1932	1.0592	3.0331	45
.57	.0472	.369	.0531	.1904	.0593	.0306	44
.5665	.0473	.3659	.0532	.1876	.0594	.0281	43
.5629	.0474	.3627	.0533	.1848	.0595	.0256	42
.5594	.0475	.3596	.0534	.182	.0596	.0231	41
3.5559	1.0476	3.3565	1.0535	3.1792	1.0598	3.0206	40
.5523	.0477	.3534	.0536	.1764	.0599	.0181	39
.5488	.0478	.3502	.0537	.1736	.06	.0156	38
.5453	.0478	.3471	.0538	.1708	.0601	.0131	37
.5418	.0479	.344	.0539	.1681	.0602	.0106	36
3.5383	1.048	3.3409	1.054	3.1653	1.0603	3.0081	35
.5348	.0481	.3378	.0541	1625	.0604	.0056	34
.5313	.0482	.3347	.0542	.1598	.0605	0031	33
.5279	.0483	.3316	.0543	.157	.0606	.0007	32
.5244	.0484	.3286	.0544	.1543	.c607	2.9982	31
3.5209	1.0485	3.3255	1.0545	3.1515	1.0608	2.9957	30
.5175	.0486	.3224	.0546	.1488	.0609	.9933	29
.514	.0487	.3194	.0547	.1461	.0611	.9908	28
.5106	.0488	.3163	.0548	.1433	.c612	.9884	27
.5072	.0489	.3133	.0549	.1406	.0613	.9859	26
3.5037	1.049	3.3102	1.055	3.1379	1.c614	2.9835	25
.5003	.0491	.3072	.0551	.1352	.0615	.981	24
.4969	.0492	.3042	.0552	.1325	.0616	.9786	23
.4935	.0493	.3011	.0553	.1298	.0617	.9762	22
.4901	.0494	.2981	.0554	.1271	.0618	.9738	21
3.4867	1.0495	3.2951	1.0555	3.1244	1.0619	2.9713	20
.4833	.0496	.2921	.0556	.1217	.062	.9689	19
.4799	.0497	.2891	.0557	.119	.0622	.9665	18
.4766	.0498	.2861	.0558	.1163	.0623	.9641	17
.4732	.0499	.2831	.0559	.1137	.0624	.9617	16
3.4698	1.05	3.2801	1.056	3.111	1.0625	2.9593	15
.4665	.0501	.2772	.0561	.1083	.0626	.9569	14
.4632	.0502	.2742	.0562	.1057	.0627	.9545	13
.4598	.0503	.2712	.0563	.103	.0628	.9521	12
.4565	.0504	.2683	.0565	.1004	.0629	.9497	11
3.4532	1.0505	3.2653	1.0566	3.0977	1.063	2.9474	10
.4498	.0506	.2624	.0567	.0951	.0632	.945	9
.4465	.0507	.2594	.0568	.0925	.0633	.9426	8
.4432	.0508	.2565	.0569	.0898	.0634	.9402	7
.4399	.0509	.2535	.057	.0872	.0635	.9379	6
3.4366	1.051	3.2506	1.0571	3.0846	1.0636	2.9355	5
.4334	.0511	.2477	.0572	.082	.0637	.9332	4
.4301	.0512	.2448	.0573	.0793	.0638	.9308	3
.4268	.0513	.2419	.0574	.0767	.0639	.9285	2
4236	.0514	.239	.0575	.0741	.0641	.9261	1
3.4203	1.0515	3.2361	1.0576	3.0715	1.0642	2.9238	0
Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	′
73°	72°		71°		70°		

	20°		21°		22°		23°		
′	Secant.	Co-sec't	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	′
0	1.0642	2.9238	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	60
1	.0643	.9215	.0713	.7883	.0787	.6675	.0865	.5575	59
2	.0644	.9191	.0714	.7862	.0788	.6656	.0866	.5558	58
3	.0645	.9168	.0715	.7841	.0789	.6637	.0868	.554	57
4	.0646	.9145	.0716	.782	.079	.6618	.0869	.5523	56
5	1.0647	2.9122	1.0717	2.7799	1.0792	2.6599	1.087	2.5506	55
6	.0648	.9098	.0719	.7778	.0793	.658	.0872	.5488	54
7	.065	.9075	.072	.7757	.0794	.6561	.0873	.5471	53
8	.0651	.9052	.0721	.7736	.0795	.6542	.0874	.5453	52
9	.0652	.9029	.0722	.7715	.0797	.6523	.0876	.5436	51
10	1.0653	2.9006	1.0723	2.7694	1.0798	2.6504	1.0877	2.5419	50
11	.0654	.8983	.0725	.7674	.0799	.6485	.0878	.5402	49
12	.0655	.896	.0726	.7653	.0801	.6466	.088	.5384	48
13	.0656	.8937	.0727	.7632	.0802	.6447	.0881	.5367	47
14	.0658	.8915	.0728	.7611	.0803	.6428	.0882	.535	46
15	1.0659	2.8892	1.0729	2.7591	1.0804	2.641	1.0884	2.5333	45
16	.066	.8869	.0731	.757	.0806	.6391	.0885	.5316	44
17	.0661	.8846	.0732	.755	.0807	.6372	.0886	.5299	43
18	.0662	.8824	.0733	.7529	.0808	.6353	.0888	.5281	42
19	.0663	.8801	.0734	.7509	.081	.6335	.0889	.5264	41
20	1.0664	2.8778	1.0736	2.7488	1.0811	2.6316	1.0891	2.5247	40
21	.0666	.8756	.0737	.7468	.0812	.6297	.0892	.523	39
22	.0667	.8733	.0738	.7447	.0813	.6279	.0893	.5213	38
23	.0668	.8711	.0739	.7427	.0815	.626	.0895	.5196	37
24	.0669	.8688	.074	.7406	.0816	.6242	.0896	.5179	36
25	1.067	2.8666	1.0742	2.7386	1.0817	2.6223	1.0897	2.5163	35
26	.0671	.8644	.0743	.7366	.0819	.6205	.0899	.5146	34
27	.0673	.8621	.0744	.7346	.082	.6186	.09	.5129	33
28	.0674	.8599	.0745	.7325	.0821	.6168	.0902	.5112	32
29	.0675	.8577	.0747	.7305	.0823	.615	.0903	.5095	31
30	1.0676	2.8554	1.0748	2.7285	1.0824	2.6131	1.0904	2.5078	30
31	.0677	.8532	.0749	.7265	.0825	.6113	.0906	.5062	29
32	.0678	.851	.075	.7245	.0826	.6095	.0907	.5045	28
33	.0679	.8488	.0751	.7225	.0828	.6076	.0908	.5028	27
34	.0681	.8466	.0753	.7205	.0829	.6058	.091	.5011	26
35	1.0682	2.8444	1.0754	2.7185	1.083	2.604	1.0911	2.4995	25
36	.0683	.8422	.0755	.7165	.0832	.6022	.0913	.4978	24
37	.0684	.84	.0756	.7145	.0833	.6003	.0914	.4961	23
38	.0685	.8378	.0758	.7125	.0834	.5985	.0915	.4945	22
39	.0686	.8356	.0759	.7105	.0836	.5967	.0917	.4928	21
40	1.0688	2.8334	1.076	2.7085	1.0837	2.5949	1.0918	2.4912	20
41	.0689	.8312	.0761	.7065	.0838	.5931	.092	.4895	19
42	.069	.829	.0763	.7045	.084	.5913	.0921	.4879	18
43	.0691	.8269	.0764	.7026	.0841	.5895	.0922	.4862	17
44	.0692	.8247	.0765	.7006	.0842	.5877	.0924	.4846	16
45	1.0694	2.8225	1.0766	2.6986	1.0844	2.5859	1.0925	2.4829	15
46	.0695	.8204	.0768	.6967	.0845	.5841	.0927	.4813	14
47	.0696	.8182	.0769	.6947	.0846	.5823	.0928	.4797	13
48	.0697	.816	.077	.6927	.0847	.5805	.0929	.478	12
49	.0698	.8139	.0771	.6908	.0849	.5787	.0931	.4764	11
50	1.0699	2.8117	1.0773	2.6888	1.085	2.577	1.0932	2.4748	10
51	.0701	.8096	.0774	.6869	.0851	.5752	.0934	.4731	9
52	.0702	.8074	.0775	.6849	.0853	.5734	.0935	.4715	8
53	.0703	.8053	.0776	.683	.0854	.5716	.0936	.4699	7
54	.0704	.8032	.0778	.681	.0855	.5699	.0938	.4683	6
55	1.0705	2.801	1.0779	2.6791	1.0857	2.5681	1.0939	2.4666	5
56	.0707	.7989	.078	.6772	.0858	.5663	.0941	.465	4
57	.0708	.7968	.0781	.6752	.0859	.5646	.0942	.4634	3
58	.0709	.7947	.0783	.6733	.0861	.5628	.0943	.4618	2
59	.071	.7925	.0784	.6714	.0862	.561	.0945	.4602	1
60	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	.0946	2.4586	0
′	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	′
	69°		68°		67°		66°		

8°		9°		10°		11°		
Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	′
1.0098	7.1853	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	60
.0099	.1704	.0125	.3807	.0155	.7493	.0188	.233	59
.0099	.1557	.0125	.369	.0155	.7398	.0188	.2252	58
.0099	.1409	.0126	.3574	.0156	.7304	.0189	.2174	57
.01	.1263	.0126	.3458	.0156	.721	.0189	.2097	56
1.01	7.1117	1.0127	6.3343	1.0157	5.7117	1.019	5.2019	55
.0101	.0972	.0127	.3228	.0157	.7023	.0191	.1942	54
.0101	.0827	.0128	.3113	.0158	.693	.0191	.1865	53
.0102	.0683	.0128	.2999	.0158	.6838	.0192	.1788	52
.0102	.0539	.0129	.2885	.0159	.6745	.0192	.1712	51
1.0102	7.0396	1.0129	6.2772	1.0159	5.6653	1.0193	5.1636	50
.0103	.0254	.013	.2659	.016	.6561	.0193	.156	49
.0103	.0112	.013	.2546	.016	.647	.0194	.1484	48
.0104	6.9971	.0131	.2434	.0161	.6379	.0195	.1409	47
.0104	.983	.0131	.2322	.0162	.6288	.0195	.1333	46
1.0104	6.969	1.0132	6.2211	1.0162	5.6197	1.0196	5.1258	45
.0105	.955	.0132	.21	.0163	.6107	.0196	.1183	44
.0105	.9411	.0133	.199	.0163	.6017	.0197	.1109	43
.0106	.9273	.0133	.188	.0164	.5928	.0198	.1034	42
.0106	.9135	.0134	.177	.0164	.5838	.0198	.096	41
1.0107	6.8998	1.0134	6.1661	1.0165	5.5749	1.0199	5.0886	40
.0107	.8861	.0135	.1552	.0165	.566	.0199	.0812	39
.0107	.8725	.0135	.1443	.0166	.5572	.02	.0739	38
.0108	.8589	.0136	.1335	.0166	.5484	.0201	.0666	37
.0108	.8454	.0136	.1227	.0167	.5396	.0201	.0593	36
1.0109	6.832	1.0136	6.112	1.0167	5.5308	1.0202	5.052	35
.0109	.8185	.0137	.1013	.0168	.5221	.0202	.0447	34
.011	.8052	.0137	.0906	.0169	.5134	.0203	.0375	33
.011	.7919	.0138	.08	.0169	.5047	.0204	.0302	32
.0111	.7787	.0138	.0694	.017	.496	.0204	.023	31
1.0111	6.7655	1.0139	6.0588	1.017	5.4874	1.0205	5.0158	30
.0111	.7523	.0139	.0483	.0171	.4788	.0205	.0087	29
.0112	.7392	.014	.0379	.0171	.4702	.0206	.0015	28
.0112	.7262	.014	.0274	.0172	.4617	.0207	4.9944	27
.0113	.7132	.0141	.017	.0172	.4532	.0207	.9873	26
1.0113	6.7003	1.0141	6.0066	1.0173	5.4447	1.0208	4.9802	25
.0114	.6874	.0142	5.9963	.0174	.4362	.0208	.9732	24
.0114	.6745	.0142	.986	.0174	.4278	.0209	.9661	23
.0115	.6617	.0143	.9758	.0175	.4194	.021	.9591	22
.0115	.649	.0143	.9655	.0175	.411	.021	.9521	21
1.0115	6.6363	1.0144	5.9554	1.0176	5.4026	1.0211	4.9452	20
.0116	.6237	.0144	.9452	.0176	.3943	.0211	.9382	19
.0116	.6111	.0145	.9351	.0177	.386	.0212	.9313	18
.0117	.5985	.0145	.925	.0177	.3777	.0213	.9243	17
.0117	.586	.0146	.915	.0178	.3695	.0213	.9175	16
1.0118	6.5736	1.0146	5.9049	1.0179	5.3612	1.0214	4.9106	15
.0118	.5612	.0147	.895	.0179	.353	.0215	.9037	14
.0119	.5488	.0147	.885	.018	.3449	.0215	.8969	13
.0119	.5365	.0148	.8751	.018	.3367	.0216	.8901	
.0119	.5243	.0148	.8652	.0181	.3286	.0216	.88[illegible]	
1.012	6.5121	1.0149	5.8554	1.0181	5.3205	1.0217	4.87[illegible]	
.012	.4999	.015	.8456	.0182	.3124	.0218	.86[illegible]	
.0121	.4878	.015	.8358	.0182	.3044	.0218	.86[illegible]	
.0121	.4757	.0151	.8261	.0183	.2963	.0210	.8[illegible]	
.0122	.4637	.0151	.8163	.0184	.2883	[illegible]		
1.0122	6.4517	1.0152	5.8067	1.0184	5.2803	[illegible]		
.0123	.4398	.0152	.797	.0185	.2724			
.0123	.4279	.0153	.7874	.0185	.2645			
.0124	.416	.0153	.7778	.0186	.2566			
.0124	.4042	.0154	.7683	.0186	.2487			
[illegible]	6.3924	1.0154	5.7588	1.0187	5.2408			
Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.			
81°		80°		79°				

′	20° Secant.	20° Co-sec't	21° Secant.	21° Co-sec't.	22° Secant.	22° Co-sec't.	23° Secant.	23° Co-sec't.	′
0	1.0642	2.9238	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	60
1	.0643	.9215	.0713	.7883	.0787	.6675	.0865	.5575	59
2	.0644	.9191	.0714	.7862	.0788	.6656	.0866	.5558	58
3	.0645	.9168	.0715	.7841	.0789	.6637	.0868	.554	57
4	.0646	.9145	.0716	.782	.079	.6618	.0869	.5523	56
5	1.0647	2.9122	1.0717	2.7799	1.0792	2.6599	1.087	2.5506	55
6	.0648	.9098	.0719	.7778	.0793	.658	.0872	.5488	54
7	.065	.9075	.072	.7757	.0794	.6561	.0873	.5471	53
8	.0651	.9052	.0721	.7736	.0795	.6542	.0874	.5453	52
9	.0652	.9029	.0722	.7715	.0797	.6523	.0876	.5436	51
10	1.0653	2.9006	1.0723	2.7694	1.0798	2.6504	1.0877	2.5419	50
11	.0654	.8983	.0725	.7674	.0799	.6485	.0878	.5402	49
12	.0655	.896	.0726	.7653	.0801	.6466	.088	.5384	48
13	.0656	.8937	.0727	.7632	.0802	.6447	.0881	.5367	47
14	.0658	.8915	.0728	.7611	.0803	.6428	.0882	.535	46
15	1.0659	2.8892	1.0729	2.7591	1.0804	2.641	1.0884	2.5333	45
16	.066	.8869	.0731	.757	.0806	.6391	.0885	.5316	44
17	.0661	.8846	.0732	.755	.0807	.6372	.0886	.5299	43
18	.0662	.8824	.0733	.7529	.0808	.6353	.0888	.5281	42
19	.0663	.8801	.0734	.7509	.081	.6335	.0889	.5264	41
20	1.0664	2.8778	1.0736	2.7488	1.0811	2.6316	1.0891	2.5247	40
21	.0666	.8756	.0737	.7468	.0812	.6297	.0892	.523	39
22	.0667	.8733	.0738	.7447	.0813	.6279	.0893	.5213	38
23	.0668	.8711	.0739	.7427	.0815	.626	.0895	.5196	37
24	.0669	.8688	.074	.7406	.0816	.6242	.0896	.5179	36
25	1.067	2.8666	1.0742	2.7386	1.0817	2.6223	1.0897	2.5163	35
26	.0671	.8644	.0743	.7366	.0819	.6205	.0899	.5146	34
27	.0673	.8621	.0744	.7346	.082	.6186	.09	.5129	33
28	.0674	.8599	.0745	.7325	.0821	.6168	.0902	.5112	32
29	.0675	.8577	.0747	.7305	.0823	.615	.0903	.5095	31
30	1.0676	2.8554	1.0748	2.7285	1.0824	2.6131	1.0904	2.5078	30
31	.0677	.8532	.0749	.7265	.0825	.6113	.0906	.5062	29
32	.0678	.851	.075	.7245	.0826	.6095	.0907	.5045	28
33	.0679	.8488	.0751	.7225	.0828	.6076	.0908	.5028	27
34	.0681	.8466	.0753	.7205	.0829	.6058	.091	.5011	26
35	1.0682	2.8444	1.0754	2.7185	1.083	2.604	1.0911	2.4995	25
36	.0683	.8422	.0755	.7165	.0832	.6022	.0913	.4978	24
37	.0684	.84	.0756	.7145	.0833	.6003	.0914	.4961	23
38	.0685	.8378	.0758	.7125	.0834	.5985	.0915	.4945	22
39	.0686	.8356	.0759	.7105	.0836	.5967	.0917	.4928	21
40	1.0688	2.8334	1.076	2.7085	1.0837	2.5949	1.0918	2.4912	20
41	.0689	.8312	.0761	.7065	.0838	.5931	.092	.4895	19
42	.069	.829	.0763	.7045	.084	.5913	.0921	.4879	18
43	.0691	.8269	.0764	.7026	.0841	.5895	.0922	.4862	17
44	.0692	.8247	.0765	.7006	.0842	.5877	.0924	.4846	16
45	1.0694	2.8225	1.0766	2.6986	1.0844	2.5859	1.0925	2.4829	15
[illegible]	[illegible]	.8204	.0768	.6967	.0845	.5841	.0927	.4813	14
[illegible]		[illegible]	.0769	.6947	.0846	.5823	.0928	.4797	13
			.077	.6927	.0847	.5805	.0929	.478	12
			.0771	.6908	.0849	.5787	.0931	.4764	11
			1.0773	2.6888	1.085	2.577	1.0932	2.4748	10
			.0774	.6869	.0851	.5752	.0934	.4731	9
			.0775	.6849	.0853	.5734	.0935	.4715	8
			.0776	.683	.0854	.5716	.0936	.4699	7
			.0778	.681	.0855	.5699	.0938	.4683	6
			1.0779	2.6791	1.0857	2.5681	1.0939	2.4666	5
			.078	.6772	.0858	.5663	.0941	.465	4
			[illegible]	.6752	.0859	.5646	.0942	.4634	3
					.0861	.5628	.0943	.4618	2
					.0862	.561	.0945	.4602	1
					1.0864	2.5593	.0946	2.4586	0
					Co-sec't.	Secant.	Co-sec't.	Secant.	′
					67°		66°		

	24°	25°		26°		27°		
…t.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	′
16	2.4586	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	60
18	.457	.1035	.3647	.1127	.2798	.1225	.2014	59
19	.4554	.1037	.3632	.1129	.2784	.1226	.2002	58
51	.4538	.1038	.3618	.1131	.2771	.1228	.1989	57
52	.4522	.104	.3603	.1132	.2757	.123	.1977	56
53	2.4506	1.1041	2.3588	1.1134	2.2744	1.1231	2.1964	55
55	.449	.1043	.3574	.1135	.273	.1233	.1952	54
56	.4474	.1044	.3559	.1137	.2717	.1235	.1939	53
58	.4458	.1046	.3544	.1139	.2703	.1237	.1927	52
59	.4442	.1047	.353	.114	.269	.1238	.1914	51
1	2.4426	1.1049	2.3515	1.1142	2.2676	1.124	2.1902	50
2	.4411	.105	.3501	.1143	.2663	.1242	.1889	49
3	.4395	.1052	.3486	.1145	.265	.1243	.1877	48
5	.4379	.1053	.3472	.1147	.2636	.1245	.1865	47
6	.4363	.1055	.3457	.1148	.2623	.1247	.1852	46
8	2.4347	1.1056	2.3443	1.115	2.261	1.1248	2.184	45
9	.4332	.1058	.3428	.1151	.2596	.125	.1828	44
1	.4316	.1059	.3414	.1153	.2583	.1252	.1815	43
2	.43	.1061	.3399	.1155	.257	.1253	.1803	42
3	.4285	.1062	.3385	.1156	.2556	.1255	1791	41
5	2.4269	1.1064	2.3371	1.1158	2.2543	1.1257	2.1778	40
6	.4254	.1065	.3356	.1159	.253	.1258	.1766	39
8	.4238	.1067	.3342	.1161	.2517	.126	.1754	38
9	.4222	.1068	.3328	.1163	.2503	.1262	.1742	37
1	.4207	.107	.3313	.1164	.249	.1264	.173	36
2	2.4191	1.1072	2.3299	1.1166	2.2477	1.1265	2.1717	35
4	.4176	.1073	.3285	.1167	.2464	.1267	.1705	34
5	.416	.1075	.3271	.1169	.2451	.1269	.1693	33
6	.4145	.1076	.3256	.1171	.2438	.127	.1681	32
8	.413	.1078	.3242	.1172	.2425	.1272	.1669	31
9	2.4114	1.1079	2.3228	1.1174	2.2411	1.1274	2.1657	30
1	.4099	.1081	.3214	.1176	.2398	.1275	.1645	29
2	.4083	.1082	.32	.1177	.2385	.1277	.1633	28
4	.4068	.1084	.3186	.1179	.2372	.1279	.162	27
5	.4053	.1085	.3172	.118	.2359	.1281	.1608	26
7	2.4037	1.1087	2.3158	1.1182	2.2346	1.1282	2.1596	25
8	.4022	.1088	.3143	.1184	.2333	.1284	.1584	24
	.4007	.109	.3129	.1185	.232	.1286	.1572	23
1	.3992	.1092	.3115	.1187	.2307	.1287	.156	22
3	.3976	.1093	.3101	.1189	.2294	.1289	.1548	21
4	2.3961	1.1095	2.3087	1.119	2.2282	1.1291	2.1536	20
5	.3946	.1096	.3073	.1192	.2269	.1293	.1525	19
7	.3931	.1098	.3059	.1193	.2256	.1294	.1513	18
8	.3916	.1099	.3046	.1195	.2243	.1296	.1501	17
	.3901	.1101	.3032	.1197	.223	.1298	.1489	16
1	2.3886	1.1102	2.3018	1.1198	2.2217	1.1299	2.1477	15
3	.3871	.1104	.3004	.12	.2204	.1301	.1465	14
4	.3856	.1106	.299	.1202	.2192	.1303	.1453	13
6	.3841	.1107	.2976	.1203	[illegible]	[illegible]	.1441	12
7	.3826	.1109	.2962	.1205			.143	11
9	2.3811	1.111	2.2949	1.1207	[illegible]		[illegible].1418	[illegible]
1	.3796	.1112	.2935	.1208			.1406	
[illegible]	.3781	.1113	.2921	.121			[illegible]	
[illegible]	.3766	.1115	.2907	.1212			[illegible]	
[illegible]	.3751	.1116	.2894	.1213				
[illegible]	2.3736	1.1118	2.288	1.1215	[illegible]			
[illegible]	.3721	.112	.2866	.1217	[illegible]			
[illegible]	.3706	.1121	.2853	.1218	[illegible]			
[illegible]	.3691	.1123	.2839	.122	[illegible]			
[illegible]	.3677	.1124	.2825	.1222	[illegible]			
[illegible]	[illegible]	1.1126	2.2812	1.1223	2.[illegible]			
	t	Co-sec't.	Secant.	Co-sec't.	Secant.			
		64°		63°				

M m

′	28° Secant.	28° Co-sec't.	29° Secant.	29° Co-sec't.	30° Secant.	30° Co-sec't.	31° Secant.	31° Co-sec't.	′
0	1.1326	2.13	1.1433	2.0627	1.1547	2	1.1666	1.9416	60
1	.1327	.1289	.1435	.0616	.1549	1.999	.1668	9407	59
2	.1329	.1277	.1437	.0605	.1551	.998	.167	.9397	58
3	.1331	.1266	.1439	.0594	.1553	.997	.1672	.9388	57
4	.1333	.1254	.1441	.0583	.1555	.996	.1674	.9378	56
5	1.1334	2.1242	1.1443	2.0573	1.1557	1.995	1.1676	1.9369	55
6	.1336	.1231	.1445	.0562	.1559	.994	.1678	.936	54
7	.1338	.1219	.1446	.0551	.1561	.993	.1681	.935	53
8	.134	.1208	.1448	.054	.1562	.992	.1683	.9341	52
9	.1341	.1196	.145	.053	.1564	.991	.1685	.9332	51
10	1.1343	2.1185	1.1452	2.0519	1.1566	1.99	1.1687	1.9322	50
11	.1345	.1173	.1454	.0508	.1568	.989	.1689	.9313	49
12	.1347	.1162	.1456	.0498	.157	.988	1691	.9304	48
13	.1349	.115	.1458	.0487	.1572	.987	.1693	.9295	47
14	.135	.1139	.1459	.0476	.1574	.986	.1695	.9285	46
15	1.1352	2.1127	1.1461	2.0466	1.1576	1.985	1.1697	1.9276	45
16	.1354	.1116	.1463	.0455	.1578	.984	.1699	.9267	44
17	.1356	.1104	.1465	.0444	.158	.983	.1701	.9258	43
18	.1357	.1093	.1467	.0434	.1582	.982	.1703	.9248	42
19	.1359	.1082	.1469	.0423	.1584	.9811	.1705	.9239	41
20	1.1361	2.107	1.1471	2.0413	1.1586	1.9801	1.1707	1.923	40
21	.1363	.1059	.1473	.0402	.1588	.9791	.1709	.9221	39
22	.1365	.1048	.1474	.0392	.159	.9781	.1712	.9212	38
23	.1366	.1036	.1476	.0381	.1592	.9771	.1714	.9203	37
24	.1368	1025	.1478	.037	.1594	.9761	.1716	.9193	36
25	1.137	2.1014	1.148	2.036	1.1596	1.9752	1.1718	1.9184	35
26	.1372	.1002	.1482	.0349	.1598	.9742	.172	.9175	34
27	.1373	.0991	.1484	.0339	.16	.9732	.1722	.9166	33
28	.1375	.098	.1486	.0329	.1602	.9722	.1724	.9157	32
29	.1377	.0969	.1488	.0318	.1604	.9713	.1726	.9148	31
30	1.1379	2.0957	1.1489	2.0308	1.1606	1.9703	1.1728	1.9139	30
31	.1381	.0946	.1491	.0297	.1608	.9693	.173	.913	29
32	.1382	.0935	.1493	.0287	.161	.9683	.1732	.9121	28
33	.1384	.0924	.1495	.0276	.1612	.9674	.1734	.9112	27
34	.1386	.0912	.1497	.0266	.1614	.9664	.1737	.9102	26
35	1.1388	2.0901	1.1499	2.0256	1.1616	1.9654	1.1739	1.9093	25
36	.139	.089	.1501	.0245	.1618	.9645	.1741	.9084	24
37	.1391	.0879	.1503	.0235	.162	.9635	.1743	.9075	23
38	.1393	.0868	.1505	.0224	.1622	.9625	.1745	.9066	22
39	.1395	.0857	.1507	.0214	.1624	.9616	.1747	.9057	21
40	1.1397	2.0846	1.1508	2.0204	1.1626	1.9606	1.1749	1.9048	20
41	.1399	.0835	.151	.0194	.1628	.9596	.1751	.9039	19
42	.1401	.0824	.1512	.0183	.163	.9587	.1753	.903	18
43	.1402	.0812	.1514	.0173	.1632	.9577	.1756	.9021	17
44	.1404	.0801	.1516	.0163	.1634	.9568	.1758	.9013	16
45	1.1406	2.079	1.1518	2.0152	1.1636	1.9558	1.176	1.9004	15
46	.1408	.0779	.152	.0142	.1638	.9549	.1762	.8995	14
47	.141	.0768	.1522	.0132	.164	.9539	.1764	.8986	13
48	.1411	.0757	.1524	.0122	.1642	.953	.1766	.8977	12
[illegible]	.1413	.0746	.1526	.0111	.1644	.952	.1768	.8968	11
	1.1415	2.0735	1.1528	2.0101	1.1646	1.951	1.177	1.8959	10
	[illegible]	.0725	.153	.0091	.1648	.9501	.1772	.895	9
		.0714	.1531	.0081	.165	.9491	.1775	.8941	8
		[illegible]	.1533	.0071	.1652	.9482	.1777	.8932	7
		[illegible]	.1535	.0061	.1654	.9473	.1779	.8924	6
		[illegible]	1.1537	2.005	1.1656	1.9463	1.1781	1.8915	5
			.1539	.004	.1658	.9454	.1783	.8906	4
			[illegible]	.003	.166	.9444	.1785	.8897	3
				.002	.1662	.9435	.1787	.8888	2
				[illegible]	.1664	.9425	.179	.8879	1
					[illegible]	1.9416	1.1792	1.8871	0
						[illegible]ant.	Co-sec't.	Secant.	′
								58°	

′	32° Secant.	32° Co-sec't.	33° Secant.	33° Co-sec't.	34° Secant.	34° Co-sec't.	35° Secant.	35° Co-sec't.	′
0	1.1792	1.8871	1.1924	1.8361	1.2062	1.7883	1.2208	1.7434	60
1	.1794	.8862	.1926	.8352	.2064	.7875	.221	.7427	59
2	.1796	.8853	.1928	.8344	.2067	.7867	.2213	.742	58
3	.1798	.8844	.193	8336	.2069	.786	.2215	.7413	57
4	.18	.8836	.1933	.8328	.2072	.7852	.2218	.7405	56
5	1.1802	1.8827	1.1935	1.832	1.2074	1.7844	1.222	1.7398	55
6	.1805	.8818	.1937	.8311	2076	.7837	.2223	.7391	54
7	.1807	.8809	.1939	.8303	.2079	.7829	.2225	.7384	53
8	.1809	.8801	.1942	.8295	.2081	.7821	.2228	.7377	52
9	.1811	.8792	.1944	.8287	.2083	.7814	223	.7369	51
10	1.1813	1.8783	1.1946	1.8279	1.2086	1.7806	1.2233	1.7362	50
11	.1815	.8785	.1948	.8271	.2088	.7798	.2235	.7355	49
12	.1818	.8766	.1951	.8263	.2091	.7791	.2238	.7348	48
13	.182	.8757	.1953	.8255	.2093	.7783	.224	.7341	47
14	.1822	.8749	.1955	.8246	.2095	.7776	.2243	.7334	46
15	1.1824	1.874	1.1958	1.8238	1.2098	1.7768	1.2245	1.7327	45
16	.1826	.8731	.196	.823	.21	.776	.2248	.7319	44
17	.1828	.8723	.1962	.8222	.2103	.7753	.225	.7312	43
18	.1831	.8714	.1964	.8214	.2105	.7745	.2253	.7305	42
19	.1833	.8706	.1967	.8206	.2107	.7738	.2255	.7298	41
20	1.1835	1.8697	1.1969	1.8198	1.211	1.773	1.2258	1.7291	40
21	.1837	.8688	.1971	.819	.2112	.7723	.226	.7284	39
22	.1839	.868	.1974	.8182	.2115	.7715	.2263	.7277	38
23	.1841	.8671	.1976	.8174	.2117	.7708	.2265	.727	37
24	.1844	.8663	.1978	.8166	.2119	.77	.2268	.7263	36
25	1.1846	1.8654	1.198	1.8158	1.2122	1.7693	1.227	1.7256	35
26	.1848	.8646	.1983	.815	.2124	.7685	.2273	.7249	34
27	.185	.8637	.1985	.8142	.2127	.7678	.2276	.7242	33
28	.1852	.8629	.1987	.8134	.2129	.767	.2278	.7234	32
29	.1855	.862	.199	.8126	.2132	.7663	.2281	.7227	31
30	1.1857	1.8611	1.1992	1.8118	1.2134	1.7655	1.2283	1.722	30
31	.1859	.8603	.1994	.811	.2136	.7648	.2286	.7213	29
32	.1861	.8595	.1997	.8102	.2139	.764	.2288	.7206	28
33	.1863	.8586	.1999	.8094	.2141	.7633	.2291	.7199	27
34	.1866	.8578	.2001	.8086	.2144	.7625	.2293	.7192	26
35	1.1868	1.8569	1.2004	1.8078	1.2146	1.7618	1.2296	1.7185	25
36	.187	.8561	.2006	.807	.2149	.761	.2298	.7178	24
37	.1872	.8552	.2008	.8062	.2151	.7603	.2301	.7171	23
38	.1874	.8544	.201	.8054	.2153	.7596	.2304	.7164	22
39	.1877	.8535	.2013	.8047	.2156	.7588	.2306	.7157	21
40	1.1879	1.8527	1.2015	1.8039	1.2158	1.7581	1.2309	1.7151	20
41	.1881	.8519	.2017	.8031	.2161	.7573	.2311	.7144	19
42	.1883	.851	.202	.8023	.2163	.7566	.2314	.7137	18
43	.1886	.8502	.2022	.8015	.2166	.7559	.2316	.713	17
44	.1888	.8493	.2024	.8007	.2168	.7551	.2319	.7123	16
45	1.189	1.8485	1.2027	1.7999	1.2171	1.7544	1.2322	1.7116	15
46	.1892	.8477	.2029	.7992	.2173	.7537	.2324	.7109	14
47	.1894	.8468	.2031	.7984	.2175	.7529	.2327	.7102	13
48	.1897	.846	.2034	.7976	.2178	.7522	.2329	.7095	12
49	.1899	.8452	.2036	.7968	.218	.7514	.2332	.7088	11
50	1.1901	1.8443	1.2039	1.796	1.2183	1.7507	1.2335	1.7081	10
51	.1903	.8435	.2041	.7953	.2185	.75	.2337	.7075	
52	.1906	.8427	.2043	.7945	.2188	.7		.7068	
53	.1908	.8418	.2046	.7937	.219	[illegible]		.7061	
54	.191	.841	.2048	.7929	.2193			.7054	
55	1.1912	1.8402	1.205	1.7921	1.2195	1		7047	
56	.1915	.8394	.2053	.7914	.2198			[illegible]	
57	.1917	.8385	.2055	.7906	.22				
58	.1919	.8377	.2057	.7898	.2203				
59	.1921	.8369	.206	.7891	.2205				
60	1.1922	1.8361	1.2062	1.7883	1.2208				
	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	[illegible]			
	57°		56°		55°				

′	36° Secant.	36° Co-sec't.	37° Secant.	37° Co-sec't.	38° Secant.	38° Co-sec't.	39° Secant.	39° Co-sec't.	′
0	1.2361	1.7013	1.2521	1.6616	1.269	1.6243	1.2867	1.589	60
1	.2363	.7006	.2524	.661	.2693	.6237	.2871	.5884	59
2	.2366	.6999	.2527	.6603	.2696	.6231	.2874	.5879	58
3	.2368	.6993	.253	.6597	.2699	.6224	.2877	.5873	57
4	.2371	.6986	.2532	.6591	.2702	.6218	.288	.5867	56
5	1.2374	1.6979	1.2535	1.6584	1.2705	1.6212	1.2883	1.5862	55
6	.2376	.6972	.2538	.6578	.2707	.6206	.2886	.5856	54
7	.2379	.6965	.2541	.6572	.271	.62	.2889	.585	53
8	.2382	.6959	.2543	.6565	.2713	.6194	.2892	.5845	52
9	.2384	.6952	.2546	.6559	.2716	.6188	.2895	.5839	51
10	1.2387	1.6945	1.2549	1.6552	1.2719	1.6182	1.2898	1.5833	50
11	.2389	.6938	.2552	.6546	.2722	.6176	.2901	.5828	49
12	.2392	.6932	.2554	.654	.2725	.617	.2904	.5822	48
13	.2395	.6925	.2557	.6533	.2728	.6164	.2907	.5816	47
14	.2397	.6918	.256	.6527	.2731	.6159	.291	.5811	46
15	1.24	1.6912	1.2563	1.6521	1.2734	1.6153	1.2913	1.5805	45
16	.2403	.6905	.2565	.6514	.2737	.6147	.2916	.5799	44
17	.2405	.6898	.2568	.6508	.2739	.6141	.2919	.5794	43
18	.2408	.6891	.2571	.6502	.2742	.6135	.2922	.5788	42
19	.2411	.6885	.2574	.6496	.2745	.6129	.2926	.5783	41
20	1.2413	1.6878	1.2577	1.6489	1.2748	1.6123	1.2929	1.5777	40
21	.2416	.6871	.2579	.6483	.2751	.6117	.2932	.5771	39
22	.2419	.6865	.2582	.6477	.2754	.6111	.2935	.5766	38
23	.2421	.6858	.2585	.647	.2757	.6105	.2938	.576	37
24	.2424	.6851	.2588	.6464	.276	.6099	.2941	.5755	36
25	1.2427	1.6845	1.2591	1.6458	1.2763	1.6093	1.2944	1.5749	35
26	.2429	.6838	.2593	.6452	.2766	.6087	.2947	.5743	34
27	.2432	.6831	.2596	.6445	.2769	.6081	.295	.5738	33
28	.2435	.6825	.2599	.6439	.2772	.6077	.2953	.5732	32
29	.2437	.6818	.2602	.6433	.2775	.607	.2956	.5727	31
30	1.244	1.6812	1.2605	1.6427	1.2778	1.6064	1.296	1.5721	30
31	.2443	.6805	.2607	.642	.2781	.6058	.2963	.5716	29
32	.2445	.6798	.261	.6414	.2784	.6052	.2966	.571	28
33	.2448	.6792	.2613	.6408	.2787	.6046	.2969	.5705	27
34	.2451	.6785	.2616	.6402	.279	.604	.2972	.5699	26
35	1.2453	1.6779	1.2619	1.6396	1.2793	1.6034	1.2975	1.5694	25
36	.2456	.6772	.2622	.6389	.2795	.6029	.2978	.5688	24
37	.2459	.6766	.2624	.6383	.2798	.6023	.2981	.5683	23
38	.2461	.6759	.2627	.6377	.2801	.6017	.2985	.5677	22
39	.2464	.6752	.263	.6371	.2804	.6011	.2988	.5672	21
40	1.2467	1.6746	1.2633	1.6365	1.2807	1.6005	1.2991	1.5666	20
41	.247	.6739	.2636	.6359	.281	.6	.2994	.5661	19
42	.2472	.6733	.2639	.6352	.2813	.5994	.2997	.5655	18
43	.2475	.6726	.2641	.6346	.2816	.5988	.3	.565	17
44	.2478	.672	.2644	.634	.2819	.5982	.3003	.5644	16
45	1.248	1.6713	1.2647	1.6334	1.2822	1.5976	1.3006	1.5639	15
46	.2483	.6707	.265	.6328	.2825	.5971	.301	.5633	14
47	.2486	.67	.2653	.6322	.2828	.5965	.3013	.5628	13
48	.2488	.6694	.2656	.6316	.2831	.5959	.3016	.5622	12
49	.249	.6687	.2659	.6309	.2834	.5953	.3019	.5617	11
50	1.2494	1.6681	1.2661	1.6303	1.2837	1.5947	1.3022	1.5611	10
51	.2497	.6674	.2664	.6297	.284	.5942	.3025	.5606	9
52	.2499	[illegible]	.2667	.6291	.2843	.5936	.3029	.56	8
53	.2502	[illegible]	.267	.6285	.2846	.593	.3032	.5595	7
54	[illegible]	[illegible]	.2673	.6279	.2849	.5924	.3035	.559	6
55	[illegible]	[illegible]	.2676	1.6273	1.2852	1.5919	1.3038	1.5584	5
56	[illegible]	[illegible]	.2679	.6267	.2855	.5913	.3041	.5579	4
57	[illegible]	[illegible]	.2681	.6261	.2858	.5907	.3044	.5573	3
58	[illegible]	[illegible]	[illegible]	[illegible]	.2861	.5901	.3048	.5568	2
59	[illegible]	[illegible]	[illegible]	[illegible]	.2864	.5896	.3051	.5563	1
60	[illegible]	[illegible]	[illegible]	[illegible]	1.2867	1.589	1.3054	1.5557	0
′	[illegible]	[illegible]	Co-sec't.	Secant.	Co-sec't.	Secant.	Co-sec't.	Secant.	′
							50°		

Natural Tangents and Co-tangents.

0°	1°		2°		3°		
Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	′
Infinite.	.017 46	57.29	.034 92	28.6363	.052 41	19.0811	60
3437.75	.017 75	6.3506	.035 21	8.3994	.052 7	8.9755	59
1718.87	.018 04	5.4415	.035 5	8.1664	.052 99	8.8711	58
145.92	.018 33	4.5613	.035 79	7.9372	.053 28	8.7678	57
859.436	.018 62	3.7086	.036 09	7.7117	.053 57	8.6656	56
687.549	.018 91	52.8821	.036 38	27.4899	.053 87	18.5645	55
572.957	.019 2	2.0807	.036 67	7.2715	.054 16	8.4645	54
491.106	.019 49	1.3032	.036 96	7.0566	.054 45	8.3655	53
29.718	.019 78	0.5485	.037 25	6.845	.054 74	8.2677	52
381.971	.020 07	49.8157	.037 54	6.6367	.055 03	8.1708	51
343.774	.020 36	49.1039	.037 83	26.4316	.055 33	18.075	50
12.521	.020 66	8.4121	.038 12	6.2296	.055 62	7.9802	49
286.478	.020 95	7.7395	.038 42	6.0307	.055 91	7.8863	48
64.441	.021 24	7.0853	.038 71	5.8348	.056 2	7.7934	47
45.552	.021 53	6.4489	.039	5.6418	.056 49	7.7015	46
229.182	.021 82	45.8294	.039 29	25.4517	.056 78	17.6106	45
14.858	.022 11	5.2261	.039 58	5.2644	.057 08	7.5205	44
02.219	.022 4	4.6386	.039 87	5.0798	.057 37	7.4314	43
190.984	.022 69	4.0661	.040 16	4.8978	.057 66	7.3432	42
80.932	.022 98	3.5081	.040 46	4.7185	.057 95	7.2558	41
171.885	.023 28	42.9641	.040 75	24.5418	.058 24	17.1693	40
63.7	.023 57	2.4335	.041 04	4.3675	.058 54	7.0837	39
56.259	.023 86	1.9158	.041 33	4.1957	.058 83	6.999	38
49.465	.024 15	1.4106	.041 62	4.0263	.059 12	6.915	37
43.237	.024 44	0.9174	.041 91	3.8593	.059 41	6.8319	36
137.507	.024 73	40.4358	.042 2	23.6945	.059 7	16.7496	35
32.219	.025 02	39.9655	.042 5	3.5321	.059 99	6.6681	34
27.321	.025 31	9.5059	.042 79	3.3718	.060 29	6.5874	33
22.774	.025 6	9.0568	.043 08	3.2137	.060 58	6.5075	32
18.54	.025 89	8.6177	.043 37	3.0577	.060 87	6.4283	31
114.589	.026 19	38.1885	.043 66	22.9038	.061 16	16.3499	30
10.892	.026 48	7.7686	.043 95	2.7519	.061 45	6.2722	29
07.426	.026 77	7.3579	.044 24	2.602	.061 75	6.1952	28
04.171	.027 06	6.956	.044 54	2.4541	.062 04	6.119	27
01.107	.027 35	6.5627	.044 83	2.3081	.062 33	6.0435	26
98.2179	.027 64	36.1776	.045 12	22.164	.062 62	15.9687	25
5.4895	.027 93	5.8006	.045 41	2.0217	.062 91	5.8945	24
2.9085	.028 22	5.4313	.045 7	1.8813	.063 21	5.8211	23
0.4633	.028 51	5.0695	.045 99	1.7426	.063 5	5.7483	22
88.1436	.028 81	4.7151	.046 28	1.6056	.063 79	5.6762	21
85.9398	.029 1	34.3678	.046 58	21.4704	.064 08	15.6048	20
3.8435	.029 39	4.0273	.046 87	1.3369	.064 37	5.534	19
1.847	.029 68	3.6935	.047 16	1.2049	.064 67	5.4638	18
79.9434	.029 97	3.3662	.047 45	1.0747	.064 96	5.3943	17
8.1263	.030 26	3.0452	.047 74	0.946	.065 25	5.3254	16
76.39	.030 55	32.7303	.048 03	20.8188	.065 54	15.2571	15
4.7292	.030 84	2.4213	.048 32	0.6932	.065 84	5.1893	14
3.139	.031 14	2.1181	.048 62	0.5691	.066 13	5.1222	13
1.6151	.031 43	1.8205	.048 91	0.4465	.066 42	5.0557	12
0.1533	.031 72	1.5284	.049 2	0.3253	.066 71	4.9898	11
68.7501	.032 01	31.2416	.049 49	20.2056	.067	14.9244	10
7.4019	.032 3	0.9599	.049 78	0.0872	.067 3	4.8596	9
6.1055	.032 59	0.6833	.050 07	19.9702	.067 59	4.7954	8
4.858	.032 88	0.4116	.050 37	9.8546	.067 88	4.7317	7
3.6567	.033 17	0.1446	.050 66	9.7403	.068 17	4.6685	6
62.4992	.033 46	29.8823	.050 95	19.6273	.068 47	14.6059	5
1.3829	.033 76	9.6245	.051 24	9.5156	.068 76	4.5438	4
0.3058	.034 05	9.3711	.051 53	9.4051	.069 05	4.4823	3
59.2659	.034 34	9.122	.051 82	9.2959	.069 34	4.4212	2
8.2612	.034 63	8.8771	.052 12	9.1879	.069 63	4.3607	1
57.29	.034 92	28.6363	.052 41	19.0811	.069 93	14.3007	0
Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	
90°	88°		87°		86°		

44°				44°				44°			
′	Secant.	Co-sec't.	′	′	Secant.	Co-sec't.	′	′	Secant.	Co-sec't.	′
0	1.3902	1.4395	60	21	1.3984	1.4305	39	41	1.4065	1.4221	19
1	.3905	.4391	59	22	.3988	.4301	38	42	.4069	.4217	18
2	.3909	.4387	58	23	.3992	.4297	37	43	.4073	.4212	17
3	.3913	.4382	57	24	.3996	.4292	36	44	.4077	.4208	16
4	.3917	.4378	56	25	1.4	1.4288	35	45	1.4081	1.4204	15
5	1.3921	1.4374	55	26	.4004	.4284	34	46	.4085	.42	14
6	.3925	.437	54	27	.4008	.428	33	47	.4089	.4196	13
7	.3929	.4365	53	28	.4012	.4276	32	48	.4093	.4192	12
8	.3933	.4361	52	29	.4016	.4271	31	49	.4097	.4188	11
9	.3937	.4357	51	30	1.402	1.4267	30	50	1.4101	1.4183	10
10	1.3941	1.4352	50	31	.4024	.4263	29	51	.4105	.4179	9
11	.3945	.4348	49	32	.4028	.4259	28	52	.4109	.4175	8
12	.3949	.4344	48	33	.4032	.4254	27	53	.4113	.4171	7
13	.3953	.4339	47	34	.4036	.425	26	54	.4117	.4167	6
14	.3957	.4335	46	35	1.404	1.4246	25	55	1.4122	1.4163	5
15	1.396	1.4331	45	36	.4044	.4242	24	56	.4126	.4159	4
16	.3964	.4327	44	37	.4048	.4238	23	57	.413	.4154	3
17	.3968	.4322	43	38	.4052	.4333	22	58	.4134	.415	2
18	.3972	.4318	42	39	.4056	.4229	21	59	.4138	.4146	1
19	.3976	.4314	41	40	1.406	1.4225	20	60	1.4142	1.4142	0
20	1.398	1.431	40								
′	Co-sec't.	Secant.	′	′	Co-sec't.	Secant.	′	′	Co-sec't.	Secant.	′
45°				45°				45°			

Preceding Table contains Natural Secants and Co-secants for every minute of the Quadrant to Radius 1.

If Degrees are taken at head of column, Minutes, Secant, and Co-secant must be taken from head also; and if they are taken at foot of column, Minutes, etc., must be taken from foot also.

Illustration.—1.05 is secant of 17° 45′ and co-secant of 72° 15′.

To Compute Secant or Co-secant of any Angle.

Rule.—Divide 1 by Cosine of angle for Secant, and by Sine for Co-secant.

Example 1.—What is secant of 25° 25′?

Cosine of angle = .903 21. Then 1 ÷ .903 21 = 1.1072, *Secant.*

2.—What is co-secant of 64° 35′?

Sine of angle = .903 21. Then 1 ÷ .903 21 = 1.1072, *Co-secant.*

To Compute Degrees, Minutes, and Seconds of a Secant or Co-secant.

When Secant is given,

Proceed as by Rule, page 402, for Sines, substituting Secants for Sines.

Example.—What is secant for 1.1607?

Th[illegible]t is 1.1606, *arc for which* = 30° 30′.

[illegible] is 1.1608, *difference between which and next less is* 1.1608 −

[illegible] tab[illegible] one given is 1.1607 − 1.1606 = .0001.

[illegible] 30° 30′ = 30° 30′ 30″.

[illegible]on,

[illegible] secants for Cosines.

Natural Tangents and Co-tangents.

0°		1°		2°		3°		
Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	′
.000 00	Infinite.	.017 46	57.29	.034 92	28.6363	.052 41	19.0811	60
.000 29	3437.75	.017 75	6.3506	.035 21	8.3994	.052 7	8.9755	59
.000 58	1718.87	.018 04	5.4415	.035 5	8.1664	.052 99	8.8711	58
.000 87	145.92	.018 33	4.5613	.035 79	7.9372	.053 28	8.7678	57
.001 16	859.436	.018 62	3.7086	.036 09	7.7117	.053 57	8.6656	56
.001 45	687.549	.018 91	52.8821	.036 38	27.4899	.053 87	18.5645	55
.001 75	572.957	.019 2	2.0807	.036 67	7.2715	.054 16	8.4645	54
.002 04	491.106	.019 49	1.3032	.036 96	7.0566	.054 45	8.3655	53
.002 33	29.718	.019 78	0.5485	.037 25	6.845	.054 74	8.2677	52
.002 62	381.971	.020 07	49.8157	.037 54	6.6367	.055 03	8.1708	51
.002 91	343.774	.020 36	49.1039	.037 83	26.4316	.055 33	18.075	50
.003 2	12.521	.020 66	8.4121	.038 12	6.2296	.055 62	7.9802	49
.003 49	286.478	.020 95	7.7395	.038 42	6.0307	.055 91	7.8863	48
.003 78	64.441	.021 24	7.0853	.038 71	5.8348	.056 2	7.7934	47
.004 07	45.552	.021 53	6.4489	.039	5.6418	.056 49	7.7015	46
.004 36	229.182	.021 82	45.8294	.039 29	25.4517	.056 78	17.6106	45
.004 65	14.858	.022 11	5.2261	.039 58	5.2644	.057 08	7.5205	44
.004 95	02.219	.022 4	4.6386	.039 87	5.0798	.057 37	7.4314	43
.005 24	190.984	.022 69	4.0661	.040 16	4.8978	.057 66	7.3432	42
.005 53	80.932	.022 98	3.5081	.040 46	4.7185	.057 95	7.2558	41
.005 82	171.885	.023 28	42.9641	.040 75	24.5418	.058 24	17.1693	40
.006 11	63.7	.023 57	2.4335	.041 04	4.3675	.058 54	7.0837	39
.006 4	56.259	.023 86	1.9158	.041 33	4.1957	.058 83	6.999	38
.006 69	49.465	.024 15	1.4106	.041 62	4.0263	.059 12	6.915	37
.006 98	43.237	.024 44	0.9174	041 91	3.8593	.059 41	6.8319	36
.007 27	137.507	.024 73	40.4358	.042 2	23.6945	.059 7	16.7496	35
.007 56	32.219	.025 02	39.9655	042 5	3.5321	.059 99	6.6681	34
.007 85	27.321	.025 31	9.5059	.042 79	3.3718	.060 29	6.5874	33
.008 14	22.774	.025 6	9.0568	.043 08	3.2137	.060 58	6.5075	32
.008 44	18.54	.025 89	8.6177	.043 37	3.0577	.060 87	6.4283	31
.008 73	114.589	.026 19	38.1885	.043 66	22.9038	.061 16	16.3499	30
.009 02	10.892	.026 48	7.7686	.043 95	2.7519	.061 45	6.2722	29
.009 31	07.426	.026 77	7.3579	.044 24	2.602	.061 75	6.1952	28
.009 6	04.171	.027 06	6.956	.044 54	2.4541	.062 04	6.119	27
.009 89	01.107	.027 35	6.5627	.044 83	2.3081	.062 33	6.0435	26
.010 18	98.2179	.027 64	36.1776	.045 12	22.164	.062 62	15.9687	25
.010 47	5.4895	.027 93	5.8006	.045 41	2.0217	.062 91	5.8945	24
.010 76	2.9085	.028 22	5.4313	.045 7	1.8813	.063 21	5.8211	23
.011 05	0.4633	.028 51	5.0695	.045 99	1.7426	.063 5	5.7483	22
.011 35	88.1436	.028 81	4.7151	.046 28	1.6056	.063 79	5.6762	21
.011 64	85.9398	.029 1	34.3678	.046 58	21.4704	.064 08	15.6048	20
.011 93	3.8435	.029 39	4.0273	.046 87	1.3369	.064 37	5.534	19
.012 22	1.847	.029 68	3.6935	.047 16	1.2049	.064 67	5.4638	18
.012 51	79.9434	.029 97	3.3662	.047 45	1.0747	.064 96	5.3943	17
.012 8	8.1263	.030 26	3.0452	.047 74	0.946	.065 25	5.3254	16
.013 09	76.39	.030 55	32.7303	.048 03	20.8188	.065 54	15.2571	15
.013 38	4.7292	.030 84	2.4213	.048 32	0.6932	.065 84	5.1893	14
.013 67	3.139	.031 14	2.1181	.048 62	0.5691	.066 13	5.1222	13
.013 96	1.6151	.031 43	1.8205	.048 91	0.4465	.066 42	5.0557	12
.014 25	0.1533	.031 72	1.5284	.049 2	0.3253	.066 71	4.9898	11
.014 55	68.7501	.032 01	31.2416	.049 49	20.2056	.067	14.9244	
.014 84	7.4019	.032 3	0.9599	.049 78	0.0872		4.8596	
.015 13	6.1055	.032 59	0.6833	.050 07	19.9702		354	
.015 42	4.858	.032 88	0.4116	.050 37	9.854			
.015 71	3.6567	.033 17	0.1446	.050 66	9.740			
.016	62.4992	.033 46	29.8823	.050 95	19.627			
.016 29	1.3829	.033 76	9.6245	.051 24	9.515			
.016 58	0.3058	.034 05	9.3711	.051 53	9.405			
.016 87	59.2659	.034 34	9.122	.051 82	9.295			
.017 16	8.2612	.034 63	8.8771	.052 12	9.187			
.017 46	57.29	.034 92	28.6363	.052 41	19.081			
Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.			
89°		88°		87°				

′	4° Tang.	4° Co-tang.	5° Tang.	5° Co-tang.	6° Tang.	6° Co-tang.	7° Tang.	7° Co-tang.
0	.06993	14.3007	.08749	11.4301	.1051	9.51436	.12278	8.14435
1	.07022	4.2411	.08778	1.3919	.1054	.48781	.12308	.12481
2	.07051	4.1821	.08807	1.354	.10569	.46141	.12338	.10536
3	.0708	4.1235	.08837	1.3163	.10599	.43515	.12367	.086
4	.0711	4.0655	.08866	1.2789	.10628	.40904	.12397	.06674
5	.07139	14.0079	.08895	11.2417	.10657	9.38307	.12426	8.04756
6	.07168	3.9507	.08925	1.2048	.10687	.35724	.12456	.02848
7	.07197	3.894	.08954	1.1681	.10716	.33154	.12485	8.00948
8	.07227	3.8378	.08983	1.1316	.10746	.30599	.12515	7.99058
9	.07256	3.7821	.09013	1.0954	.10775	.28058	.12544	.97176
10	.07285	13.7267	.09042	11.0594	.10805	9.2553	.12574	7.95302
11	.07314	3.6719	.09071	1.0237	.10834	.23016	.12603	.93438
12	.07344	3.6174	.09101	0.9882	.10863	.20516	.12633	.91582
13	.07373	3.5634	.0913	0.9529	.10893	.18028	.12662	.89734
14	.07402	3.5098	.09159	0.9178	.10922	.15554	.12692	.87895
15	.07431	13.4566	.09189	10.8829	.10952	9.13093	.12722	7.86064
16	.07461	3.4039	.09218	0.8483	.10981	.10646	.12751	.84242
17	.0749	3.3515	.09247	0.8139	.11011	.08211	.12781	.82428
18	.07519	3.2996	.09277	0.7797	.1104	.05789	.1281	.80622
19	.07548	3.248	.09306	0.7457	.1107	.03379	.1284	.78825
20	.07578	13.1969	.09335	10.7119	.11099	9.00983	.12869	7.77035
21	.07607	3.1461	.09365	0.6783	.11128	8.98598	.12899	.75254
22	.07636	3.0958	.09394	0.645	.11158	.96227	.12929	.7348
23	.07665	3.0458	.09423	0.6118	.11187	.93867	.12958	.71715
24	.07695	2.9962	.09453	0.5789	.11217	.9152	.12988	.69957
25	.07724	12.9469	.09482	10.5462	.11246	8.89185	.13017	7.68208
26	.07753	2.8981	.09511	0.5136	.11276	.86862	.13047	.66466
27	.07782	2.8496	.09541	0.4813	.11305	.84551	.13076	.64732
28	.07812	2.8014	.0957	0.4491	.11335	.82252	.13106	.63005
29	.07841	2.7536	.096	0.4172	.11364	.79964	.13136	.61287
30	.0787	12.7062	.09629	10.3854	.11394	8.77689	.13165	7.59575
31	.07899	2.6591	.09658	0.3538	.11423	.75425	.13195	.57872
32	.07929	2.6124	.09688	0.3224	.11452	.73172	.13224	.56176
33	.07958	2.566	.09717	0.2913	.11482	.70931	.13254	.54487
34	.07987	2.5199	.09746	0.2602	.11511	.68701	.13284	.52806
35	.08017	12.4742	.09776	10.2294	.11541	8.66482	.13313	7.51132
36	.08046	2.4288	.09805	0.1988	.1157	.64275	.13343	.49465
37	.08075	2.3838	.09834	0.1683	.116	.62078	.13372	.47806
38	.08104	2.339	.09864	0.1381	.11629	.59893	.13402	.46154
39	.08134	2.2946	.09893	0.108	.11659	.57718	.13432	.44509
40	.08163	12.2505	.09923	10.078	.11688	8.55555	.13461	7.42871
41	.08192	2.2067	.09952	0.0483	.11718	.53402	.13491	.4124
42	.08221	2.1632	.09981	0.0187	.11747	.51259	.13521	.39616
43	.08251	2.1201	.10011	9.9893	.11777	.49128	.1355	.37999
44	.0828	2.0772	.1004	.96007	.11806	.47007	.1358	.36389
45	.08309	12.0346	.10069	9.93101	.11836	8.44896	.13609	7.34786
46	.08339	1.9923	.10099	.90211	.11865	.42795	.13639	.3319
47	.08368	1.9504	.10128	.87338	.11895	.40705	.13669	.316
48	.08397	1.9087	.10158	.84482	.11924	.38625	.13698	.30018
49	.08427	1.8673	.10187	.81641	.11954	.36555	.13728	.28442
50	.0[illegible]	[illegible]8262	.10216	9.78817	.11983	8.34496	.13758	7.26873
51	[illegible]	[illegible]853	.10246	.76009	.12013	.32446	.13787	.2531
52	[illegible]	[illegible]8	.10275	.73217	.12042	.30406	.13817	.23754
53	[illegible]	[illegible]5	.10305	.70441	.12072	.28376	.13846	.22204
54	[illegible]	[illegible]45	.10334	.6768	.12101	.26355	.13876	.20661
55	[illegible]	[illegible]248	.10363	9.64935	.12131	8.24345	.13906	7.19125
56	[illegible]	[illegible]53	.10393	.62205	.1216	.22344	.13935	.17594
57	[illegible]	[illegible]	.10422	.5949	.1219	.20352	.13965	.16071
58	[illegible]	[illegible]	.104[illegible]	.56791	.12219	.1837	.13995	.14553
59	[illegible]	[illegible]	[illegible]	.54106	.12249	.16398	.14024	.13042
60	[illegible]	[illegible]	[illegible]	[illegible]436	.1227[illegible]	8.14435	.14054	7.11537
	[illegible]	[illegible]	[illegible]	[illegible]	Co[illegible]	[illegible]	Co-tang.	Tang.
								82°

′	8°		9°		10°		11°		′
	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	
0	.14054	7.11537	.15838	6.31375	.17633	5.67128	.19438	5.14455	60
1	.14084	.10038	.15868	.30189	.17663	.66165	.19468	.13658	59
2	.14113	.08546	.15898	.29007	.17693	.65205	.19498	.12862	58
3	.14143	.07059	.15928	.27829	.17723	.64248	.19529	.12069	57
4	.14173	.05579	.15958	.26655	.17753	.63295	.19559	.11279	56
5	.14202	7.04105	.15988	6.25486	.17783	5.62344	.19589	5.1049	55
6	.14232	.02637	.16017	.24321	.17813	.61397	.19619	.09704	54
7	.14262	.01174	.16047	.2316	.17843	.60452	.19649	.08921	53
8	.14291	6.99718	.16077	.22003	.17873	.59511	.1968	.08139	52
9	.14321	.98268	.16107	.20851	.17903	.58573	.1971	.0736	51
10	.14351	6.96823	.16137	6.19703	.17933	5.57638	.1974	5.06584	50
11	.14381	.95385	.16167	.18559	.17963	.56706	.1977	.05809	49
12	.1441	.93952	.16196	.17419	.17993	.55777	.19801	.05037	48
13	.1444	.92525	.16226	.16283	.18023	.54851	.19831	.04267	47
14	.1447	.91104	.16256	.15151	.18053	.53927	.19861	.03499	46
15	.14499	6.89688	.16286	6.14023	.18083	5.53007	.19891	5.02734	45
16	.14529	.88278	.16316	.12899	.18113	.5209	.19921	.01971	44
17	.14559	.86874	.16346	.11779	.18143	.51176	.19952	.0121	43
18	.14588	.85475	.16376	.10664	.18173	.50264	.19982	.00451	42
19	.14618	.84082	.16405	.09552	.18203	.49356	.20012	4.99695	41
20	.14648	6.82694	.16435	6.08444	.18233	5.48451	.20042	4.9894	40
21	.14678	.81312	.16465	.0734	.18263	.47548	.20073	.98188	39
22	.14707	.79936	.16495	.0624	.18293	.46648	.20103	.97438	38
23	.14737	.78564	.16525	.05143	.18323	.45751	.20133	.9669	37
24	.14767	.77199	.16555	.04051	.18353	.44857	.20164	.95945	36
25	.14796	6.75838	.16585	6.02962	.18383	5.43966	.20194	4.95201	35
26	.14826	.74483	.16615	.01878	.18414	.43077	.20224	.9446	34
27	.14856	.73133	.16645	.00797	.18444	.42192	.20254	.93721	33
28	.14886	.71789	.16674	5.9972	.18474	.41309	.20285	.92984	32
29	.14915	.7045	.16704	.98646	.18504	.40429	.20315	.92249	31
30	.14945	6.69116	.16734	5.97576	.18534	5.39552	.20345	4.91516	30
31	.14975	.67787	.16764	.9651	.18564	.38677	.20376	.90785	29
32	.15005	.66463	.16794	.95448	.18594	.37805	.20406	.90056	28
33	.15034	.65144	.16824	.9439	.18624	.36936	.20436	.8933	27
34	.15064	.63831	.16854	.93335	.18654	.3607	.20466	.88605	26
35	.15094	6.62523	.16884	5.92283	.18684	5.35206	.20497	4.87882	25
36	.15124	.61219	.16914	.91235	.18714	.34345	.20527	.87162	24
37	.15153	.59921	.16944	.90191	.18745	.33487	.20557	.86444	23
38	.15183	.58627	.16974	.89151	.18775	.32631	.20588	.85727	22
39	.15213	.57339	.17004	.88114	.18805	.31778	.20618	.85013	21
40	.15243	6.56055	.17033	5.8708	.18835	5.30928	.20648	4.843	20
41	.15272	.54777	.17063	.86051	.18865	.3008	.20679	.8359	19
42	.15302	.53503	.17093	.85024	.18895	.29235	.20709	.82882	18
43	.15332	.52234	.17123	.84001	.18925	.28393	.20739	.82175	17
44	.15362	.5097	.17153	.82982	.18955	.27553	.2077	.81471	16
45	.15391	6.4971	.17183	5.81966	.18986	5.26715	.208	4.80769	15
46	.15421	.48456	.17213	.80953	.19016	.2588	.2083	.80068	
47	.15451	.47206	.17243	.79944	.19046	.25048	.20861	.7937	
48	.15481	.45961	.17273	.78938	.19076	.24218	.20891	.78673	
49	.15511	.4472	.17303	.77936	.19106	.23391	.20921	.77978	
50	.1554	6.43484	.17333	5.76937	.19136	5.22566	.20952	4.77286	
51	.1557	.42253	.17363	.75941	.19166	.21744	.20982	.76595	
52	.156	.41026	.17393	.74949	.19197	.20925	.21013	.75906	
53	.1563	.39804	.17423	.7396	.19227	.20107	.21042	.75219	
54	.1566	.38587	.17453	.72974	.19257	.19293		.74534	
55	.15689	6.37374	.17483	5.71992	.19287	5.1848		.72851	
56	.15719	.36165	.17513	.71013	.19317	.17671			
57	.15749	.34961	.17543	.70037	.19347	.16863			
58	.15779	.33761	.17573	.69064	.19378	.1605			
59	.15809	.32566	.17603	.68094	.19408	.15256			
60	.15838	6.31375	.17633	5.67128	.19438	5.14455			
′	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.			
	81°		80°		79°				

′	20° Tang.	20° Co-tang.	21° Tang.	21° Co-tang.	22° Tang.	22° Co-tang.	23° Tang.	23° Co-tang.	′
0	[illegible]	2.747 48	.383 86	2.605 09	.404 03	2.475 09	.424 47	[illegible]	60
1	.364 3	.744 99	.384 2	.602 83	.404 36	.473 02	.424 82	[illegible]	59
2	.364 63	.742 51	.384 53	.600 57	.404 7	.470 95	[illegible]	[illegible]	58
3	.364 96	.740 04	.384 87	.598 31	.405 04	.468 88	.425 51	.350 15	57
4	.365 29	.737 58	.385 2	.596 06	.405 38	.466 82	[illegible]	[illegible]	56
5	.365 62	2.735 09	.385 53	2.593 81	.405 72	2.464 76	[illegible]	[illegible]	55
6	.365 95	.732 63	.385 87	[illegible]	[illegible]	.462 7	.426 54	.344 47	54
7	[illegible]	.730 17	.386 2	.589 32	.406 4	.460 65	.426 88	[illegible]	53
8	.366 61	.727 71	.386 54	[illegible]	.406 74	[illegible]	.427 22	[illegible]	52
9	[illegible]	.725 26	[illegible]	.584 84	[illegible]	.456 55	.427 57	[illegible]	51
10	.367 27	2.722 81	.387 21	2.582 61	.407 41	2.454 51	[illegible]	[illegible]	50
11	[illegible]	.720 36	.387 54	.580 38	.407 75	.452 47	.428 25	[illegible]	49
12	[illegible]	.717 92	.387 87	.578 15	.408 09	.450 43	[illegible]	[illegible]	48
13	[illegible]	.715 48	.388 21	.575 93	.408 43	.448 39	[illegible]	.331 3	47
14	[illegible]	[illegible]	.388 54	.573 71	.408 77	.446 35	.429 29	[illegible]	46
15	[illegible]	2.710 62	.388 88	2.571 5	.409 11	2.444 33	[illegible]	[illegible]	45
16	[illegible]	.708 19	.389 21	.569 28	.409 45	.442 3	[illegible]	[illegible]	44
17	[illegible]	.705 77	.389 55	.567 07	.409 79	.440 27	.430 32	[illegible]	43
18	[illegible]	.703 35	.389 88	.564 87	.410 13	.438 25	.430 67	.321 97	42
19	.370 24	.700 94	.390 22	.562 66	.410 47	.436 23	.431 01	[illegible]	41
20	.370 57	2.698 53	.390 55	2.560 46	.410 81	2.434 22	.431 36	[illegible]	40
21	.370 9	.696 12	.390 89	.558 27	.411 15	.432 2	.431 7	[illegible]	39
22	.371 24	.693 71	.391 22	.556 08	.411 49	.430 19	.432 05	[illegible]	38
23	.371 57	.691 31	.391 56	.553 89	.411 83	.428 19	.432 39	.312 71	37
24	.371 9	.688 92	.391 9	.551 7	.412 17	.426 18	.432 74	.310 86	36
25	.372 23	2.686 53	.392 23	2.549 52	.412 51	2.424 18	.433 08	[illegible]	35
26	.372 56	.684 14	.392 57	.547 34	.412 85	.422 18	.433 43	[illegible]	34
27	.372 89	[illegible]	.392 9	.545 16	.413 19	.420 19	.433 78	[illegible]	33
28	.373 22	.679 37	.393 24	.542 99	.413 53	.418 19	.434 12	[illegible]	32
29	.373 55	.677	.393 57	.540 82	.413 87	.416 2	.434 47	[illegible]	31
30	[illegible]	2.674 62	.393 91	2.538 65	.414 21	2.414 21	[illegible]	2.299 84	30
31	[illegible]	.672 25	.394 25	.536 48	.414 55	.412 23	[illegible]	[illegible]	29
32	.374 55	.669 89	.394 58	.534 32	.414 9	.410 25	.435 5	[illegible]	28
33	[illegible]	.667 52	.394 92	.532 17	[illegible]	.408 27	.435 85	[illegible]	27
34		.665 16	.395 26	.530 01	[illegible]	.406 29	[illegible]	[illegible]	26
35		2.662 81	.395 59	2.527 86	[illegible]	2.404 32	[illegible]	[illegible]	25
36		.660 46	.395 93	.525 71	[illegible]	.402 35	[illegible]	[illegible]	24
37		.658 11	.396 26	.523 57	[illegible]	.400 38	[illegible]	.287 1	23
38		.655 76	.396 6	.521 42	[illegible]	.398 41	[illegible]	[illegible]	22
39		[illegible] 42	.396 94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21
40		[illegible] 09	.397 27	2.517 15	[illegible]	2.394 49	[illegible]	2.281 67	20
41		.648 75	.397 61	.515 02	.417 97	.392 53	[illegible]	.279 87	19
42		.646 42	.397 95	[illegible]	.418 31	.390 58	.438 97	[illegible]	18
43		.644 1	.398 29	.510 75	.418 65	[illegible]	.439 32	[illegible]	17
44	3	.641 77	.398 62	.508 64	.418 99	[illegible]	[illegible]	[illegible]	16
45	7	2.639 45	.398 96	2.506 52	.419 33	2.384 73	.440 01	[illegible]	15
46	2	.637 14	.399 3	.504 4	.419 68	.382 79	[illegible]	.270 88	14
47	.53	.634 83	.399 63	.502 29	.420 02	.380 84	.440 71	.269 09	13
48	[illegible]	.632 52	.399 97	.500 18	.420 36	.378 91	.441 05	.267 3	12
49	2	.630 21	.400 31	.498 07	.420 7	.376 97	.441 4	[illegible]	11
50	53	2.627 91	.400 65	2.495 97	.421 05	2.375 04	.441 75	2.263 74	10
51	[illegible]	[illegible]	.400 98	.493 86	[illegible]	.373 11	.442 1	.261 96	9
52		[illegible]	.401 32	.491 77	.421 73	.371 18	.442 44	.260 18	8
53			.401 66	.489 67	.422 07	.369 25	.442 79	.258 4	7
54			[illegible]	.487 58	.422 42	.367 33	.443 14	.256 63	6
55			[illegible] 34	2.485 49	.422 76	2.365 41	.443 49	2.254 86	5
56			[illegible]	.483 4	.423 1	.363 40	.443 84	.253 09	4
57			[illegible]	.481 32	.423 45	.361 58	.444 18	.251 32	3
58			[illegible]	.479 24	.423 79	.359 67	.444 53	.249 56	2
59			[illegible]	.477 16	.424 13	.357 76	.444 88	.247 8	1
60			[illegible]	2.475 09	.424 47	2.355 85	.445 23	[illegible]	0
			[illegible]g.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	
			68°		67°		66°		

24°		25°		26°		27°		
G.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	′
23	2.24604	.46631	2.14451	.48773	2.0503	.50953	1.96261	60
58	.24428	.46666	.14288	.48809	.04879	.50989	.9612	59
93	.24252	.46702	.14125	.48845	.04728	.51026	.95979	58
27	.24077	.46737	.13963	.48881	.04577	.51063	.95838	57
62	.23902	.46772	.13801	.48917	.04426	.51099	.95698	56
97	2.23727	.46808	2.13639	.48953	2.04276	.51136	1.95557	55
32	.23553	.46843	.13477	.48989	.04125	.51173	.95417	54
67	.23378	.46879	.13316	.49026	.03975	.51209	.95277	53
02	.23204	.46914	.13154	.49062	.03825	.51246	.95137	52
37	.2303	.4695	.12993	.49098	.03675	.51283	.94997	51
72	2.22857	.46985	2.12832	.49134	2.03526	.51319	1.94858	50
07	.22683	.47021	.12671	.4917	.03376	.51356	.94718	49
42	.2251	.47056	.12511	.49206	.03227	.51393	.94579	48
77	.22337	.47092	.1235	.49242	.03078	.5143	.9444	47
·12	.22164	.47128	.1219	.49278	.02929	.51467	.94301	46
47	2.21992	.47163	2.1203	.49315	2.0278	.51503	1.94162	45
·82	.21819	.47199	.11871	.49351	.02631	.5154	.94023	44
17	.21647	.47234	.11711	.49387	.02483	.51577	.93885	43
52	.21475	.4727	.11552	.49423	.02335	.51614	.93746	42
87	.21304	.47305	.11392	.49459	.02187	.51651	.93608	41
:22	2.21132	.47341	2.11233	.49495	2.02039	.51688	1.9347	40
!57	.20961	.47377	.11075	.49532	.01891	.51724	.93332	39
:92	.2079	.47412	.10916	.49568	.01743	.51761	.93195	38
27	.20619	.47448	.10758	.49604	.01596	.51798	.93057	37
62	.20449	.47483	.106	.4964	.01449	.51835	.9292	36
97	2.20278	.47519	2.10442	.49677	2.01302	.51872	1.92782	35
32	.20108	.47555	.10284	.49713	.01155	.51909	.92645	34
67	.19938	.4759	.10126	.49749	.01008	.51946	.92508	33
02	.19769	.47625	.09969	.49786	.00862	.51983	.92371	32
37	.19599	.47662	.09811	.49822	.00715	.5202	.92235	31
73	2.1943	.47698	2.09654	.49858	2.00569	.52057	1.92098	30
508	.19261	.47733	.09498	.49894	.00423	.52094	.91962	29
543	.19092	.47769	.09341	.49931	.00277	.52131	.91826	28
578	.18923	.47805	.09184	.49967	.00131	.52168	.9169	27
713	.18755	.4784	.09028	.50004	1.99986	.52205	.91554	26
748	2.18587	.47876	2.08872	.5004	1.99841	.52242	1.91418	25
784	.18419	.47912	.08716	.50076	.99695	.52279	.91282	24
819	.18251	.47948	.0856	.50113	.9955	.52316	.91147	23
854	.18084	.47984	.08405	.50149	.99406	.52353	.91012	22
889	.17916	.48019	.0825	50185	.99261	.5239	.90876	21
924	2.17749	.48055	2.08094	.50222	1.99116	.52427	1.90741	20
96	.17582	.48091	.07939	.50258	.98972	.52464	.90607	19
995	.17416	.48127	.07785	.50295	.98828	.52501	.90472	18
03	.17249	.48163	.0763	.50331	.98684	.52538	.90337	17
065	.17083	.48198	.07476	.50368	.9854	.52575	.90203	16
101	2.16917	.48234	2.07321	.50404	1.98396	.52613	1.90069	15
·136	.16751	.4827	.07167	.50441	.98253	.5265	.89935	14
·171	.16585	.48306	.07014	.50477	.9811	.52687	.89801	13
206	.1642	.48342	.0686	.50514	.97966	.52724	.89667	12
242	.16255	.48378	.06706	.5055	.97823	.52761	.89533	11
277	2.1609	.48414	2.06553	.50587	1.9768	.52798	1.894	
312	.15925	.4845	.064	.50623	.97538	.52836	.892	
348	.1576	.48486	.06247	.5066	.97395	.52873	.891	
383	.15596	.48521	.06094	.50696	.97253	.5291	.89	
418	.15432	.48557	.05942	.50733	.97111	.52947	.888	
454	2.15268	.48593	2.0579	.50769	1.96969	.52984	1.887	
489	.15104	.48629	.05637	.50806	.96827	.53022	.886	
525	.1494	.48665	.05485	.50843	.96685	.53059	.88	
56	.14777	.48701	.05333	.50879	.96544	.53096	.88	
595	.14614	.48737	.05182	.50916	.96402	.53134	.882	
31	2.14451	.48773	2.0503	.50953	1.96261	.53171	1.88073	
G.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	
65°		64°		63°		62°		

′	28° Tang.	28° Co-tang.	29° Tang.	29° Co-tang.	30° Tang.	30° Co-tang.	31° Tang.	31° Co-tang.	
0	.531 71	1.880 73	.554 31	1.804 05	.577 35	1.732 05	.600 86	1.664 28	
1	.532 08	.879 41	.554 69	.802 81	.577 74	.730 89	.601 26	.663 18	
2	.532 46	.878 09	.555 07	.801 58	.578 13	.729 73	.601 65	.662 09	
3	.532 83	.876 77	.555 45	.800 34	.578 51	.728 57	.602 05	.660 99	
4	.533 2	.875 46	.555 83	.799 11	.578 9	.727 41	.602 45	.659 9	
5	.533 58	1.874 15	.556 21	1.797 88	.579 29	1.726 25	.602 84	1.658 81	
6	.533 95	.872 83	.556 59	.796 65	.579 68	.725 09	.603 24	.657 72	
7	.534 32	.871 52	.556 97	.795 42	.580 07	.723 93	.603 64	.656 63	
8	.534 7	.870 21	.557 36	.794 19	.580 46	.722 78	.604 03	.655 54	
9	.535 07	.868 91	.557 74	.792 96	.580 85	.721 63	.604 43	.654 45	
10	.535 45	1.867 6	.558 12	1.791 74	.581 24	1.720 47	.604 83	1.653 37	
11	.535 82	.866 3	.558 5	.790 51	.581 62	.719 32	.605 22	.652 28	
12	.536 2	.864 99	558 88	.789 29	.582 01	.718 17	.605 62	.651 2	
13	.536 57	.863 69	.559 26	.788 07	.582 4	.717 02	.606 02	.650 11	
14	.536 94	.862 39	.559 64	.786 85	.582 79	.715 88	.606 42	.649 03	
15	.537 32	1.861 09	.560 03	1.785 63	.583 18	1.714 73	.606 81	1.647 95	
16	.537 69	.859 79	.560 41	.784 41	.583 57	.713 58	.607 21	.646 87	
17	.538 07	.858 5	.560 79	.783 19	.583 96	.712 44	.607 61	.645 79	
18	.538 44	.857 2	561 17	.781 98	.584 35	.711 29	.608 01	.644 71	
19	.538 82	.855 91	.561 56	.780 77	.584 74	.710 15	.608 41	.643 63	
20	.539 2	1.854 62	561 94	1.779 55	.585 13	1.709 01	.608 81	1.642 56	
21	.539 57	.853 33	.562 32	.778 34	.585 52	.707 87	.609 21	.641 48	
22	.539 95	.852 04	.562 7	.777 13	.585 91	.706 73	.609 6	.640 41	
23	.540 32	.850 75	.563 09	.775 92	.586 31	.705 6	.61	.639 34	
24	.540 7	.849 46	.563 47	.774 71	.586 7	.704 46	.610 4	.638 26	
25	.541 07	1.848 18	.563 85	1.773 51	.587 09	1.703 32	.610 8	1.637 19	
26	.541 45	.846 89	.564 24	.772 3	.587 48	.702 19	.611 2	.636 12	
27	.541 83	.845 61	.564 62	771 1	.587 87	.701 06	.611 6	.635 05	
28	.542 2	.844 33	565	.769 9	.588 26	.699 92	.612	.633 98	
29	.542 58	.843 05	.565 39	.768 69	.588 65	.698 79	.612 4	.632 92	
30	.542 96	1.841 77	.565 77	1.767 49	.589 04	1.697 66	.612 8	1.631 85	
31	.543 33	.840 49	.566 16	.766 3	.589 44	.696 53	.613 2	.630 79	
32	.543 71	.839 22	566 54	.765 1	.589 83	.695 41	.613 6	.629 72	
33	.544 09	.837 94	.566 93	.763 9	.590 22	.694 28	.614	.628 66	
34	.544 46	.836 67	.567 31	.762 71	.590 61	.693 16	.614 4	.627 6	
35	.544 84	1.835 4	.567 69	1.761 51	.591 01	1.692 03	.614 8	1.626 54	
36	.545 22	.834 13	.568 08	.760 32	.591 4	.690 91	615 2	.625 48	
37	.545 6	.832 86	.568 46	.759 13	.591 79	.689 79	.615 61	.624 42	
38	.545 97	.831 59	.568 85	.757 94	.592 18	.688 66	.616 01	.623 36	
39	.546 35	.830 33	.569 23	756 75	.592 58	.687 54	.616 41	.622 3	
40	.546 73	1.829 06	.569 62	1.755 56	.592 97	1.686 43	.616 81	1.621 25	
41	.547 11	.827 8	.57	.754 37	.593 36	.685 31	.617 21	.620 19	
42	.547 48	.826 54	.570 39	.753 19	593 76	.684 19	.617 61	.619 14	
43	.547 86	.825 28	.570 78	.752	594 15	.683 08	.618 01	.618 08	
44	.548 24	.824 02	.571 16	.750 82	.594 54	.681 96	.618 42	.617 03	
45	.548 62	1.822 76	.571 55	1.749 64	594 94	1.680 85	.618 82	1.615 98	15
46	.549	.821 5	.571 93	.748 46	595 33	.679 74	.619 22	.614 93	14
47	.549 38	.820 25	.572 32	.747 28	.595 73	.678 63	619 62	.613 88	13
[illegible]	.549 75	.818 99	.572 71	.746 1	.596 12	.677 52	.620 03	.612 83	12
	.550 13	.817 74	.573 09	.744 92	.596 51	.676 41	.620 43	.611 79	11
	.550 51	1.816 49	.573 48	1.743 75	.596 91	1.675 3	.620 83	1.610 74	10
	.550 89	.815 24	.573 86	.742 57	.597 3	.674 19	.621 24	.609 7	9
	[illegible]7	.813 99	.574 25	.741 4	.597 7	.673 09	621 64	.608 65	8
		.812 74	.574 64	.740 22	.598 09	.671 98	.622 04	.607 61	7
		.811 5	.575 03	.739 05	.598 49	.670 88	.622 45	.606 57	6
		[illegible]25	.575 41	1.737 88	.598 88	1.669 78	622 85	1.605 53	5
		[illegible]	.575 8		.599 28	.668 67	.623 25	.604 49	4
					[illegible]67	.667 57	.623 66	.603 45	3
					[illegible]7	.666 47	.624 06	.602 41	2
					[illegible]46	.665 38	.624 46	.601 37	1
					[illegible]86	1.664 28	.624 87	1.600 33	
					[illegible]ng.	Tang.	Co-tang.	Tan[illegible]	
					59°		58°		

32°		33°		34°		35°		
Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	′
624 87	1.600 33	.649 41	1.539 86	.674 51	1.482 56	.700 21	1.428 15	60
625 27	.599 3	.649 82	.538 88	.674 93	.481 63	.700 64	.427 26	59
625 68	.598 26	.650 23	.537 91	.675 36	.480 7	.701 07	.426 38	58
626 08	.597 23	.650 65	.536 93	.675 78	.479 77	.701 51	.425 5	57
626 49	.596 2	.651 06	.535 95	.676 2	.478 85	.701 94	.424 62	56
626 89	1.595 17	.651 48	1.534 97	.676 63	1.477 92	.702 38	1.423 74	55
.627 3	.594 14	.651 89	.534	.677 05	.476 99	.702 81	.422 86	54
.627 7	.593 11	.652 31	.533 02	.677 48	.476 07	.703 25	.421 98	53
.628 11	.592 08	.652 72	.532 05	.677 9	.475 14	.703 68	.421 1	52
.628 52	.591 05	.653 14	.531 07	.678 32	.474 22	.704 12	.420 22	51
.628 92	1.590 02	.653 55	1.530 1	.678 75	1.473 3	.704 55	1.419 34	50
.629 33	.589	.653 97	.529 13	.679 17	.472 38	.704 99	.418 47	49
.629 73	.587 97	.654 38	.528 16	.679 6	.471 46	.705 42	.417 59	48
.630 14	.586 95	.654 8	.527 19	.680 02	.470 53	.705 86	.416 72	47
.630 55	.585 93	.655 21	.526 22	.680 45	.469 62	.706 29	.415 84	46
.630 95	1.584 9	.655 63	1.525 25	.680 88	1.468 7	.706 73	1.414 97	45
.631 36	.583 88	.656 04	.524 29	.681 3	.467 78	.707 17	.414 09	44
.631 77	.582 86	.656 46	.523 32	.681 73	.466 86	.707 6	.413 22	43
.632 17	.581 84	.656 88	.522 35	.682 15	.465 95	.708 04	.412 35	42
.632 58	.580 83	.657 29	.521 39	.682 58	.465 03	.708 48	.411 48	41
.632 99	1.579 81	.657 71	1.520 43	.683 01	1.464 11	.708 91	1.410 61	40
.633 4	.578 79	.658 13	.519 46	.683 43	.463 2	.709 35	.409 74	39
.633 8	.577 78	.658 54	.518 5	.683 86	.462 29	.709 79	.408 87	38
.634 21	.576 76	.658 96	.517 54	.684 29	.461 37	.710 23	.408	37
.634 62	.575 75	.659 38	.516 58	.684 71	.460 46	.710 66	.407 14	36
.635 03	1.574 74	.659 8	1.515 62	.685 14	1.459 55	.711 1	1.406 27	35
.635 44	.573 72	.660 21	.514 66	.685 57	.458 64	.711 54	.405 4	34
.635 84	.572 71	.660 63	.513 7	.686	.457 73	.711 98	.404 54	33
.636 25	.571 7	.661 05	.512 75	.686 42	.456 82	.712 42	.403 67	32
.636 66	.570 69	.661 47	.511 79	.686 85	.455 92	.712 85	.402 81	31
.637 07	1.569 69	.661 89	1.510 84	.687 28	1.455 01	.713 29	1.401 95	30
.637 48	.568 68	.662 3	.509 88	.687 71	.454 1	.713 73	.401 09	29
.637 89	.567 67	.662 72	.508 93	.688 14	.453 2	.714 17	.400 22	28
.638 3	.566 67	.663 14	.507 97	.688 57	.452 29	.714 61	.399 36	27
.638 71	.565 66	.663 56	.507 02	.689	.451 39	.715 05	.398 5	26
.639 12	1.564 66	.663 98	1.506 07	.689 42	1.450 49	.715 49	1.397 64	25
.639 53	.563 66	.664 4	.505 12	.689 85	.449 58	.715 93	.396 79	24
.639 94	.562 65	.664 82	.504 17	.690 28	.448 68	.716 37	.395 93	23
.640 35	.561 65	.665 24	.503 22	.690 71	.447 78	.716 81	.395 07	22
.640 76	.560 65	.665 66	.502 28	.691 14	.446 88	.717 25	.394 21	21
.641 17	1.559 66	.666 08	1.501 33	.691 57	1.445 98	.717 69	1.393 36	20
.641 58	.558 66	.666 5	.500 38	.692	.445 08	.718 13	.392 5	19
.641 99	.557 66	.666 92	.499 44	.692 43	.444 18	.718 57	.391 65	18
.642 4	.556 66	.667 34	.498 49	.692 86	.443 29	.719 01	.390 79	17
.642 81	.555 67	.667 76	.497 55	.693 29	.442 39	.719 46	.389 94	16
.643 22	1.554 67	.668 18	1.496 61	.693 72	1.441 49	.719 9	1.389 09	15
.643 63	.553 68	.668 6	.495 66	.694 16	.440 6	.720 34	.388 24	14
.644 04	.552 69	.669 02	.494 72	.694 59	.439 7	.720 78	.387 38	13
.644 46	.551 7	.669 44	.493 78	.695 02	.438 81	.721 22	.386 53	12
.644 87	.550 71	.669 86	.492 84	.695 45	.437 92	.721 66	.385 68	11
.645 28	1.549 72	.670 28	1.491 9	.695 88	1.437 03	.722 11	1.384 84	
.645 69	.548 73	.670 71	.490 97	.696 31	.436 14	.722 55		
.646 1	.547 74	.671 13	.490 03	.696 75	.435 25	.722 99		
.646 52	.546 75	.671 55	.489 09	.697 18	.434 36	.723 44		
.646 93	.545 76	.671 97	.488 16	.697 61	.433 47	.723 88		
.647 34	1.544 78	.672 39	1.487 22	.698 04	1.432 58	.724 32		
.647 75	.543 79	.672 82	.486 29	.698 47	.431 69	.724 77		
.648 17	.542 81	.673 24	.485 36	.698 91	.430 8	.725 2		
.648 58	.541 83	.673 66	.484 42	.699 34	.429 92	.725 65		
.648 99	.540 85	.674 09	.483 49	.699 77	.429 03	.726 1		
.649 41	1.539 86	.674 51	1.482 56	.700 21	1.428 15	.726 54		
Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.		
57°		56°		55°		54°		

	36°		37°		38°		39°		
′	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	
0	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.2349	
1	.72699	.37554	.75401	.32624	.78175	.27917	.81027	.23416	
2	.72743	.3747	.75447	.32544	.78222	.27841	.81075	.23343	
3	.72788	.37386	.75492	.32464	.78269	.27764	.81123	.2327	
4	.72832	.37302	.75538	.32384	.78316	.27688	.81171	.23196	
5	.72877	1.37218	.75584	1.32304	.78363	1.27611	.8122	1.23123	
6	.72921	.37134	.75629	.32224	.7841	.27535	.81268	.2305	
7	.72966	.3705	.75675	.32144	.78457	.27458	.81316	.22977	
8	.7301	.36967	.75721	.32064	.78504	.27382	.81364	.22904	
9	.73055	.36883	.75767	.31984	.78551	.27306	.81413	.22831	
10	.731	1.368	.75812	1.31904	.78598	1.2723	.81461	1.22758	
11	.73144	.36716	.75858	.31825	.78645	.27153	.8151	.22685	
12	.73189	.36633	.75904	.31745	.78692	.27077	.81558	.22612	
13	.73234	.36549	.7595	.31666	.78739	.27001	.81606	.22539	
14	.73278	1.36466	.75996	.31586	.78786	.26925	.81655	.22467	
15	.73323	.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	
16	.73368	.363	.76088	.31427	.78881	.26774	.81752	.22321	
17	.73413	.36217	.76134	.31348	.78928	.26698	.818	.22249	
18	.73457	.36133	.7618	.31269	.78975	.26622	.81849	.22176	
19	.73502	.36051	.76226	.3119	.79022	.26546	.81898	.22104	
20	.73547	1.35968	.76272	1.3111	.7907	1.26471	.81946	1.22031	
21	.73592	.35885	.76318	.31031	.79117	.26395	.81995	.21959	
22	.73637	.35802	.76364	.30952	.79164	.26319	.82044	.21886	
23	.73681	.35719	.7641	.30873	.79212	.26244	.82092	.21814	
24	.73726	.35637	.76456	.30795	.79259	.26169	.82141	.21742	
25	.73771	1.35554	.76502	1.30716	.79306	1.26093	.8219	1.2167	
26	.73816	.35472	.76548	.30637	.79354	.26018	.82238	.21598	
27	.73861	.35389	.76594	.30558	.79401	.25943	.82287	.21526	
28	.73906	.35307	.7664	.3048	.79449	.25867	.82336	.21454	
29	.73951	.35224	.76686	.30401	.79496	.25792	.82385	.21382	
30	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.2131	
31	.74041	.3506	.76779	.30244	.79591	.25642	.82483	.21238	
32	.74086	.34978	.76825	.30166	.79639	.25567	.82531	.21166	
33	.74131	.34896	.76871	.30087	.79686	.25492	.8258	.21094	
34	.74176	.34814	.76918	.30009	.79734	.25417	.82629	.21023	
35	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	
36	.74267	.3465	.7701	.29853	.79829	.25268	.82727	.20879	
37	.74312	.34568	.77057	.29775	.79877	.25193	.82776	.20808	
38	.74357	.34487	.77103	.29696	.79924	.25118	.82825	.20736	
39	.74402	.34405	.77149	.29618	.79972	.25044	.82874	.20665	
40	.74447	1.34323	.77196	1.2954	.8002	1.24969	.82923	1.20593	
41	.74492	.34242	.77242	.29463	.80067	.24895	.82972	.20522	
42	.74538	.3416	.77289	.29385	.80115	.2482	.83022	.20451	
43	.74583	.34079	.77335	.29307	.80163	.24746	.83071	.20379	
44	.74628	.33998	.77382	.29229	.80211	.24672	.8312	.20308	
45	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	
46	.74719	.33835	.77475	.29074	.80306	.24523	.83218	.20166	
47	.74764	.33754	.77521	.28997	.80354	.24449	.83268	.20095	
48	.7481	.33673	.77568	.28919	.80402	.24375	.83317	.20024	
49	.74855	.33592	.77615	.28842	.8045	.24301	.83366	.19953	
50	.749	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	
51	.74946	.3343	.77708	.28687	.80546	.24153	.83465	.19811	
52	.74991	.33349	.77754	.2861	.80594	.24079	.83514	.1974	
53	.75037	.33268	.77801	.28533	.80642	.24005	.83564	.19669	
54	.75082	.33187	.77848	.28456	.8069	.23931	.83613	.19599	
55	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	
56	.75173	.33026	.77941	.28302	.80786	.23784	.83712	.19457	
57	.75219	.32946	.77988	.28225	.80834	.2371	.83761	.19387	
58	.75264	.32865	.78035	.28148	.80882	.23637	.83811	.19316	
59	.7531	.32785	.78082	.28071	.8093	.23563	.8386	.19246	
60	.75355	1.32704	.78129	1.27994	.80978	1.2349	.8391	1.19175	
′	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	
	53°		52°		51°		50°		

40°		41°		42°		43°		
Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	′
39 1	1.191 75	.869 29	1.150 37	.900 4	1.110 61	.932 52	1.072 37	60
39 6	.191 05	.869 8	.149 69	.900 93	.109 96	.933 06	.071 74	59
40 09	.190 35	.870 31	.149 02	.901 46	.109 31	.933 6	.071 12	58
40 59	.189 64	.870 82	.148 34	.901 99	.108 67	.934 15	.070 49	57
41 08	.188 94	.871 33	.147 67	.902 51	.108 02	.934 69	.069 87	56
41 58	1.188 24	.871 84	1.146 99	.903 04	1.107 37	.935 24	1.069 25	55
42 08	.187 54	.872 36	.146 32	.903 57	.106 72	.935 78	.068 62	54
42 58	.186 84	.872 87	.145 65	.904 1	.106 07	.936 33	.068	53
43 07	.186 14	.873 38	.144 98	.904 63	.105 43	.936 88	.067 38	52
43 57	.185 44	.873 89	.144 3	.905 16	.104 78	.937 42	.066 76	51
44 07	1.184 74	.874 41	1.143 63	.905 69	1.104 14	.937 97	1.066 13	50
44 57	.184 04	.874 92	.142 96	.906 21	.103 49	.938 52	.065 51	49
45 07	.183 34	.875 43	.142 29	.906 74	.102 85	.939 06	.064 89	48
45 56	.182 64	.875 95	.141 62	.907 27	.102 2	.939 61	.064 27	47
46 06	.181 94	.876 46	.140 95	.907 81	.101 56	.940 16	.063 65	46
46 56	1.181 25	.876 98	1.140 28	.908 34	1.100 91	.940 71	1.063 03	45
47 06	.180 55	.877 49	.139 61	.908 87	.100 27	.941 25	.062 41	44
47 56	.179 86	.878 01	.138 94	.909 4	.099 63	.941 8	.061 79	43
48 06	.179 16	.878 52	.138 28	.909 93	.098 99	.942 35	.061 17	42
48 56	.178 46	.879 04	.137 61	.910 46	.098 34	.942 9	.060 56	41
49 06	1.177 77	.879 55	1.136 94	.910 99	1.097 7	.943 45	1.059 94	40
49 56	.177 08	.880 07	.136 27	.911 53	.097 06	.944	.059 32	39
50 06	.176 38	.880 59	.135 61	.912 06	.096 42	.944 55	.058 7	38
50 57	.175 69	.881 1	.134 94	.912 59	.095 78	.945 1	.058 09	37
51 07	.175	.881 62	.134 28	.913 13	.095 14	.945 65	.057 47	36
51 57	1.174 3	.882 14	1.133 61	.913 66	1.094 5	.946 2	1.056 85	35
52 07	.173 61	.882 65	.132 95	.914 19	.093 86	.946 76	.056 24	34
52 57	.172 92	.883 17	.132 28	.914 73	.093 22	.947 31	.055 62	33
53 07	.172 23	.883 69	.131 62	.915 26	.092 58	.947 86	.055 01	32
53 58	.171 54	.884 21	.130 96	.915 8	.091 95	.948 41	.054 39	31
54 08	1.170 85	.884 73	1.130 29	.916 33	1.091 31	.948 96	1.053 78	30
54 58	.170 16	.885 24	129 63	.916 87	.090 67	.949 52	.053 17	29
55 09	.169 47	.885 76	.128 97	.917 4	.090 03	.950 07	.052 55	28
55 59	.168 78	.886 28	.128 31	.917 94	.089 4	.950 62	.051 94	27
56 09	.168 09	.886 8	.127 65	.918 47	.088 76	.951 18	.051 33	26
56 6	1.167 41	.887 32	1.126 99	.919 01	1.088 13	.951 73	1.050 72	25
57 1	.166 72	.887 84	.126 33	.919 55	.087 49	.952 29	.050 1	24
57 61	.166 03	.888 36	.125 67	.920 08	.086 86	.952 84	.049 49	23
58 11	.165 35	.888 88	.125 01	.920 62	.086 22	.953 4	.048 88	22
58 62	.164 66	.889 4	.124 35	.921 16	.085 59	.953 95	.048 27	21
59 12	1.163 98	.889 92	1.123 69	.921 7	1.084 96	.954 51	1.047 66	20
59 63	.163 29	.890 45	.123 03	.922 23	.084 32	.955 06	.047 05	19
60 14	.162 61	.890 97	.122 38	.922 77	.083 69	.955 62	.046 44	18
60 64	.161 92	.891 49	.121 72	.923 31	.083 06	.956 18	.045 83	17
61 15	.161 24	.892 01	.121 06	.923 85	.082 43	.956 73	.045 22	16
61 66	1.160 56	.892 53	1.120 41	.924 39	1.081 79	.957 29	1.044 61	
62 16	.159 87	.893 06	.119 75	.924 93	.081 16	.957 85	.044 01	
62 67	.159 19	.893 58	.119 09	.925 47	.080 53	.958 41	.043 4	
63 18	.158 51	.894 1	.118 44	.926 01	.079 9	.958 97	.042 79	
63 68	.157 83	.894 63	.117 78	.926 55	.079 27	.959 52	.042 18	
64 19	1.157 15	.895 15	1.117 13	.927 09	1.078 64	.960 08	1.041 58	
864 7	.156 47	.895 67	.116 48	.927 63	.078 01	.960 64	.040 97	
865 21	.155 79	.896 2	.115 82	.928 17	.077 38	.96 [illegible]	.04[illegible]	
865 72	.155 11	.896 72	.115 17	.928 72	.076 76	.961 76	[illegible]	
866 23	.154 43	.897 25	.114 52	.929 26	.076 13	.962 32	[illegible]	
866 74	1.153 75	.897 77	1.113 87	.929 8	1.075 5	.962 88	1.[illegible]	
.867 25	.153 08	.898 3	.113 21	.930 34	.074 87	.963 44	[illegible]	
.867 76	.152 4	.898 83	.112 56	.930 88	.074 25	.964		
.868 27	.151 72	.899 35	.111 91	.931 43	.073 62	.964 57		
.868 78	.151 04	.899 88	.111 26	.931 97	.072 99	.965 13		
.869 29	1.150 37	.900 4	1.110 61	.932 52	1.072 37	.965 69		
Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	Tang.	Co-tang.	
		48°			47°		46°	

	44°				44°				44°		
′	Tang.	Co-tang.	′	′	Tang.	Co-tang.	′	′	Tang.	Co-tang.	′
0	.965 69	1.035 53	60	21	.977 56	1.022 95	39	41	.989 01	1.011 12	19
1	.966 25	1.034 93	59	22	.978 13	1.022 36	38	42	.989 58	1.010 53	18
2	.966 81	1.034 33	58	23	.978 7	1.021 76	37	43	.990 16	1.009 94	17
3	.967 38	1.033 72	57	24	.979 27	1.021 17	36	44	.990 73	1.009 35	16
4	.967 94	1.033 12	56	25	.979 84	1.020 57	35	45	.991 31	1.008 76	15
5	.968 5	1.032 52	55	26	.980 41	1.019 98	34	46	.991 89	1.008 18	14
6	.969 07	1.031 92	54	27	.980 98	1.019 39	33	47	.992 47	1.007 59	13
7	.969 63	1.031 32	53	28	.981 55	1.018 79	32	48	.993 04	1.007 01	12
8	.970 2	1.030 72	52	29	.982 13	1.018 2	31	49	.993 62	1.006 42	11
9	.970 76	1.030 12	51	30	.982 7	1.017 61	30	50	.994 2	1.005 83	10
10	.971 33	1.029 52	50	31	.983 27	1.017 02	29	51	.994 78	1.005 25	9
11	.971 89	1.028 92	49	32	.983 84	1.016 42	28	52	.995 36	1.004 67	8
12	.972 46	1.028 32	48	33	.984 41	1.015 83	27	53	.995 94	1.004 08	7
13	.973 02	1.027 72	47	34	.984 99	1.015 24	26	54	.996 52	1.003 5	6
14	.973 59	1.027 13	46	35	.985 56	1.014 65	25	55	.997 1	1.002 91	5
15	.974 16	1.026 53	45	36	.986 13	1.014 06	24	56	.997 68	1.002 33	4
16	.974 72	1.025 93	44	37	.986 71	1.013 47	23	57	.998 26	1.001 75	3
17	.975 29	1.025 33	43	38	.987 28	1.012 88	22	58	.998 84	1.001 16	2
18	.975 86	1.024 74	42	39	.987 86	1.012 29	21	59	.999 42	1.000 58	1
19	.976 43	1.024 14	41	40	.988 43	1.011 7	20	60	1	1	0
20	.977	1.023 55	40								
′	Co-tang.	Tang.	′	′	Co-tang.	Tang.	′	′	Co-tang.	Tang.	′
	45°				45°				45°		

Preceding Table contains Natural Tangents and Co-tangents for every minute of the quadrant, to the radius of 1.

If Degrees are taken at head of columns, Minutes, Tangents, and Co-tangents must be taken from head also; and if they are taken at foot of columns, Minutes, etc., must be taken from foot also.

ILLUSTRATION.—.1974 is tangent for 11° 10′, and co-tangent for 78° 50′.

To Compute Tangents and Co-tangents for Seconds.

Ascertain tangent or co-tangent of angle for degrees and minutes from Table; take difference between it and tangent or co-tangent next below it.

Then as 60 seconds is to difference, so are seconds given to result required, which is to be added to tangent and subtracted from co-tangent.

ILLUSTRATION.—What is the tangent and co-tangent of 54° 40′ 40″?

Tangent of 50° 40′, per Table = 1.410 61 }
Tangent of 54° 41′, " = 1.411 48 } .000 87 *difference.*

Then 60 : .000 87 :: 40 : .000 58, which, added to 1.410 61 = 1.411 19 *tangent.*

Co-tangent of 54° 40′, per Table = .708 91 }
Co-tangent of 54° 41′, " = .708 48 } .000 43 *difference.*

Then 60° : .000 43 :: 40 : 29, which, subtracted from .708 91 = .708 62 *co-tangent.*

To Compute Tangent or Co-tangent of any Angle in Degrees, Minutes, and Seconds.

[illegible]ide Sine by Cosine for Tangent, and Cosine by Sine for Co-tangent.

[illegible]—What is tangent of 25° 18′?

[illegible]ine = .427 36; cosine = .904 08. Then $\frac{.427\ 36}{.904\ 08}$ = .4727 *tangent.*

[illegible]pute Number of Degrees, Minutes, and Seconds of a given Tangent or Co-tangent.

[illegible] *is given.*—Proceed as by Rule, page 402, for Sines, [illegible] for Sines.

[illegible]angent for 1.411 10?

[illegible] Next greatest tang[illegible]

[illegible]061—1.411 19 = [illegible]
= 54° 40′ 40″.

[illegible] page 402, for Co[illegible]

AEROSTATICS.

Atmospheric Air consists, by volume, of Oxygen 21, and Nitrogen 79 ırts; and in 10 000 parts there are 4.9 parts of Carbonic acid gas. y weight, it consists of 77 parts of Oxygen, and 23 of Nitrogen.

One cube foot of Atmospheric Air at surface of Earth, when barome- ›r is at 30 ins., and at a temperature of 32°, weighs 565.0964 grains = ›80 728 lbs. avoirdupois, being 773.19 times lighter than water.

Specific gravity compared with water, at 62.418 = .001 293 345.

Mean weight of a column of air a foot square, and of an altitude ıual to height of atmosphere (barometer 30 ins.), is 2124.6875 lbs. = 4.7548 lbs. per sq. inch = support of 34.0393 feet of water.

Standard pound is computed with a mercurial barometer at 30 ins.; hence, s a cube inch of mercury at 60° weighs .490 776 9 lbs., pressure of atmos- here at 60° = 14.723 307 lbs. per square inch.

12.3873 cube feet of air weigh a pound, and its weight varies about gr. for each degree of heat.

Extreme height of barometer in latitude 30° to 35° N. = 30.21 ins.

Rate of expansion of Air, *and all other Elastic Fluids* for all temperatures, s essentially uniform. From 32° to 212° they expand from 1000 to 1376 'olumes = .002 088 or $\frac{1}{479}$th part of their bulk for every degree of heat. 'rom 212° to 680° they expand from 1376 to 2322 = .002 021 for each de- ree of heat.

Thus, if volume of air at 132° is required. 132° − 32° = 100, and 1000 + 100 × .002 088 = 1209 *volumes*.

Height, at Equator is estimated at 300 feet greater than at Poles, its nean height at 45° latitude.

In like latitudes, air loses 1° for every 340 feet in height above level of sea.

Below surface of Earth, temperature increases.

Elasticity of air is inversely as space it occupies, and directly as its density.

When altitude of air is taken in arithmetical proportion, its *Rarity* will be in geometric proportion. Thus, at 7 miles above surface of Earth, air is 4 times rarer or lighter than at Earth's surface; at 14 miles, 16 times; at 21 miles, 64 times, and so on.

Density of an aeriform fluid mass at 32° and at $t°$ will be to each other as 1 + .002 088 ($t° - 32°$) is to 1.

For Volume, Pressure, and Density of Air, see Heat, page 521.

Altitude of Atmosphere at ordinary density is = a column of mercr ins. in height, divided by specific gravity of air compared with mercr

Hence 30 ins. = 2.5 feet, which, divided by .000 094 987, specific g of air compared with mercury, = 26 319 *feet* = 4.985 *miles*.

Gay Lussac, Humboldt, and Boussingault estimated it at a minin 30 miles, Sir John Herschell 83, Bravais 66 to 100, Dalto 180 or 204 miles.

The aqueous vapor always existing in air, in a grea being lighter than air, diminishes its weight in mixing equal, its quantity is greater the higher the temp is *to be considered by increasing* the multiplier

ther and Coxwell, in 1862, ascended in a balloon to

At temperature of 32°, mean velocity of sound is 1089 feet per second. It is increased or diminished about one foot for each degree of temperature below or above 32°.

Velocity of sound in water is estimated at 4750 feet per second.

Velocity of Sound at Various Temperatures.

°	Per Second.	°	Per Second.	°	Per Second.	°	Per Second.
	Feet.		Feet.		Feet.		Feet.
5	1056	32	1089	68	1122	95	1152
14	1070	50	1102	77	1132	104	1161
23	1079	59	1112	86	1142	113	1171

Motions of air and all gases, by force of gravity, are precisely alike to those of fluids.

Sensation of hearing, or sound, cannot exist in an absolute vacuum. The human voice can be heard a distance of 3300 feet.

Echo.—At a less distance than 100 feet there is not a sufficient interval between the delivery of a sound and its reflection to render one perceptible.

To Compute Distances by Velocity of Sound in Air.

$1089 \times 13\sqrt{1 + [.002\,008\,(t - 32)]} = v$, *distance in feet per second, t representing temperature of air.*

ILLUSTRATION.—Flash of a cannon from a vessel was observed 13 seconds before report was heard; temperature of air 60°; what was distance to vessel?

$1089 \times 13\sqrt{1 + [.002\,088\,(60^\circ - 32)]} = 1089 \times 13 \times 1.029 = 14\,567.55$ *feet* $= 2.76$ *miles.*

Theoretical velocity with which air will flow into a vacuum, if wholly unobstructed, is $\sqrt{2gh} = 1347.4$ *feet per second.* In operation, however, it is $1347.4 \times .707 = 952.61$ *feet.*

To Compute Velocity of Air Flowing into a Vacuum.

$\sqrt{2gh} \times c = v$ *in feet per second, c representing coefficient of efflux.*

Coefficients for openings are as follows:

Circular aperture in a thin plate.................................. .65 to .7
Cylindrical adjutage.......... .92 | Conical adjutage.......... .93

Velocity of Sound in Several Solids.

Velocity in Air = 1.

Lead	3.9	Zinc	9.8	Pine	12.5	Glass	11.9	Steel	14.3
Gold	5.6	Oak	9.9	Copper	11.2	Pine	12.5	Iron	15.1

To Compute Elevations by a Barometer.

*Approximately** 60 000 (log. B — log. *b*) C = *height in feet;* B *and b representing heights of barometer at lower and upper stations,* and C *correction due to* T + *t or temperatures of lower and upper stations.*

Values of C or T + *t*.

°	C	°	C	°	C	°	C	°	C	°	C	°	C
[illegible]	[illegible]	60	.996	80	1.018	100	1.04	120	1.062	140	1.084	160	1.106
[illegible]	[illegible]	62	.998	82	1.02	102	1.042	122	1.064	142	1.087	162	1.108
[illegible]	[illegible]	[illegible]	1	84	1.022	104	1.044	124	1.067	144	1.089	164	1.111
[illegible]	[illegible]	[illegible]	1.002	86	1.024	106	1.047	126	1.069	146	1.091	166	1.113
[illegible]	[illegible]	[illegible]	[illegible]	88	1.027	108	1.049	128	1.071	148	1.093	168	1.115
[illegible]	[illegible]	[illegible]	[illegible]	90	[illegible]	110	1.051	130	1.073	150	1.096	170	1.117
[illegible]	[illegible]	[illegible]	[illegible]	92	[illegible]	112	[illegible]	132	1.076	152	1.098	172	1.12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	134	1.078	154	1.1	174	1.122
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	136	1.08	156	1.102	176	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.082	158	1.104	178	[illegible]

* [illegible] S. Lee, U.S. Top. Eng., 1853.

Their *values* vary approximately .0011 per degree.

	Upper Station.	Lower Station.
ILLUSTRATION.—Thermometer	70.4	77.6
Barometer	23.66	30.05

$C = 77.6 + 70.4 = 1.093$, $\log. B = 1.4778$, $\log. b = 1.374$.

Then $60\,000 \times (1.4778 - 1.374) \times 1.093 = 6807.2$ *feet.*

To Compute Elevations by a Thermometer.

$520\ B + B^2 \times C =$ *height in feet.* B *representing temperature of water boiling* (*elevated station deducted from* 212°.

Correction for temperatures of air at lower and upper stations, or $T + t$, to be take from table, page 428, as before.

ILLUSTRATION.—Temperature of water boiling at upper station 192°; temperatu of air 50° and 32°. $C = 1.02$.

Then $520 \times \overline{212 - 192} + \overline{212 - 192}^2 \times 1.02 = 10\,8\,08$ *feet.*

To Compute Capacity of a Balloon, etc., see page 218.

Barometer.

Elevations by Barometer Readings. (*Astronomer Royal.*)

Mean Temperature of Air 50°.

For correction for temperature, see note at foot.

Height.	Barom.	Height.	Barom.	Height.	Barom.	Height.	Barom.	Height.	Barom.
Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.
0	31	600	30.325	1500	29.34	4000	26.769	7 000	23.979
50	30.943	650	30.269	1600	29.233	4250	26.524	7 500	23.543
100	30.886	700	30.214	1750	29.072	4500	26.282	8 000	23.115
150	30.83	750	30.159	1800	29.019	4750	26 042	8 500	22.695
200	30.773	800	30.103	2000	28.807	5000	25.804	9 000	22.282
250	30.717	850	30.048	2250	28.544	5250	25.569	9 500	21.877
300	30.661	900	29.993	2500	28.283	5500	25.335	10 000	21.479
350	30.604	1000	29.883	2750	28.025	5750	25.104	10 500	21.089
400	30.548	1100	29.774	3000	27.769	6000	24.875	11 000	20.706
450	30.492	1200	29.665	3250	27.515	6250	24.648	11 500	20.329
500	30.436	1300	29.556	3500	27.264	6500	24.423	12 000	19.959
550	30.381	1400	29.448	3750	27.015	6750	24.2	12 500	19.952

Barometer.

Correction for Capillary Attraction to be added in Inches.

Diameter of tube........	.6	.55	.5	.45	.4	.55	.3	.25	.2	.1
Correction, unboiled.....	.004	005	.007	.01	.014	.02	.025	04	.059	.08
Correction, boiled	.002	.003	004	005	.007	01	.014	.02	029	.04

To Compute Height.

RULE.—Subtract reading at lower station from reading at upper station, differenc is height in feet.

Table assumes mean temperature of atmosphere to be 50° F. or 10° C. For ot temperatures following correction must be applied.

Add together temperatures at upper and lower station. If this sum, in de in F., is greater than 100°, *increase* height by $\frac{1}{1000}$ part for every degree of e above 100°; if sum is less than 100°, *diminish* height by $\frac{1}{1000}$ part for every de of defect from 100°. Or if sum in C° is greater than 20°, *increase* height by part for every degree of excess above 20°; if sum is less than 20°, *diminish* he by $\frac{1}{556}$ part for every degree of defect from 20°.

Barometer Indications.

Increasing storm.—If mercury falls during a high wind from S. or S.

Violent but short.—If fall be rapid.

Less violent but of longer continuance.—If fall be slow.

Snow.—If mercury falls when thermometer is low.

Improved weather.—When a gradual continuous rise of mercu falling thermometer.

Heavy gales from N.—*Soon* after *first* rise of mercury from a very low point.
Unsettled weather.—With a *rapid* rise of mercury.
Settled weather.—With a *slow* rise of mercury.
Very fine weather.—With a continued *steadiness* of mercury with dry air.
Stormy weather with rain (or snow).—With a rapid and considerable fall of mercury.
Threatening, unsettled weather.—With an alternate rising and falling of mercury.
Lightning *only*.—When mercury is low, storm being beyond horizon.
Fine weather.—With a rosy sky at sunset.
Wind and rain.—When sky has a sickly greenish hue.
Rain.—When clouds are of a dark Indian red.
Foul weather or much wind.—When sky is red in morning.

Weather Glasses.

Explanatory Card. *Vice-Admiral Fitzroy, F. R. S.*

Barometer Rises for Northerly wind (including from N. W. by *N.* to E.), for dry, or less wet weather, for less wind, or for more than one of these changes—
Except on a few occasions when rain, hail, or snow comes from N. with *strong* wind.

Barometer Falls for Southerly wind (including from S. E. by *S.* to W.), for wet weather, for stronger wind, or for more than one of these changes—
Except on a few occasions when *moderate* wind with rain (or snow) comes from N.

For change of wind toward Northerly directions, *a Thermometer falls.*

For change of wind toward Southerly directions, *a Thermometer rises.*

Moisture or dampness in air (shown by a Hygrometer) increases *before* rain, fog, or dew.

Add one tenth of an inch to observed height for each hundred feet Barometer is above half-tide level.

Average height of Barometer, in England, at sea-level, is about 29.94 inches; and *average* temperature of air is nearly 50 degrees (latitude of London).

Thermometer falls about one degree for each 300 feet of elevation from ground, but varies with wind.

"When the wind shifts against the sun,
Trust it not, for back it will run."

First rise after very low
Indicates a stronger blow.

Long foretold—long last,
Short notice—soon past.

Rarefaction of Air.

In consequence of rarefaction of air, gas loses of its illuminating power 1 cube inch for each 2.69 feet of elevation above the sea. (*M. Bremond.*)

Clouds.

Classification.—1. *Cirrus*—Like to a feather, commonly termed *Mare's* 2. *Cirro-cumulus*—Small round clouds, termed *mackerel sky.* ɔ-*stratus*—Concave or undulated stratus. 4. *Cumulus*—Conical, lusters, termed *wool-packs* and *cotton balls.* 5. *Cumulo-stratus*— r mixed. 6. *Nimbus*—A cumulus spreading out in arms, and ing rain beneath it. 7. *Stratus*—A level sheet.

Xirrus is most elevated.

—Clouds have been seen at a greater height than 37 000 feet.

—A … arent moderate speed, they attain a velocity of 80

Lightning.

– —Developed with great rapidity.
Globular—When the electric
ed at a comparatively lower
h appears to rest upon the

WEATHER INDICATIONS.

...r.	Clouds.	Sky.
...nd	Soft or delicate-looking and indefinite outlines.	Gray in morning and light, delicate tints and low dawn.
.	Hard-edged, oily-looking, and tawny or copper-colored, and the more hard, "greasy," and ragged, the more wind.	High dawn, and sunset of a bright yellow.
...ily.	Light scud alone.	
	Small and inky.	Sunset of a pale yellow.
...nd	Light scud driving across heavy masses.	Orange or copper color.
...nd	Hard defined outlines.	Gaudy unusual hues.
...of .	High upper, cross lower in a direction different to their course or that of wind.	

General.

–When sea-birds fly early and far out, when dew is deposited, and when a ...nfined in a bottle of water, will curl up at the bottom.

—Clear atmosphere near to horizon and light atmospheric pressure, or a ...earing day," as it is termed.

...—When sea-birds remain near to shore or fly inland.

Snow, or Wind.—When a leech, confined in a bottle of water, will rise ex... to the surface.

...ler.—When a leech, confined as above, will be much excited and leave the

...of Indications of Fair Weather, in Days, Compared to one of Rain.

From an extended series of observations. (*Lowe.*)

Dew	4.5	Mock Sun or Moon	3.3
...tratus in a valley	7.2	Stars falling abundant	3.2
Clouds at sunset	2.9	Stars bright	3.4
...alo	1.9	Stars dim	1.5
...and rayless	10.3	Stars scintillated	6
...e and sparkling	1	Aurora borealis	1.8
...rost	4.2	Toads in evening	2.4
...Ialo	1	Landrails noisy	13
...urr, or rough-edged	2.8	Ducks and Geese noisy	2.3
...im	2	Fish rising	1.5
...sing red	7	Smoke rising vertically	5

...weather-foretelling plants, see page 185.

ATMOSPHERIC AIR.

...pure air contains Oxygen 20.96, Nitrogen 79, and Carbonic Aci...
...espired by a human being in one hour is about 15 cube...
...grains of carbonic acid, corresponding to 137 grai...
this time about 200 grains of water will be exhaled b...
...ng this period there would be consumed about 415 gr...
...e hour, then, there would be vitiated 73 cube feet pur...

...an, *weighing 150 lbs.*, requires 930 cube feet of air pe...
...*air he breathes may not* contain more than 1 per 1...
...*which proportion its* impurity becomes sensible to ...
...*fore, to* have 800 cube feet of well ventilated space.

...k:

An adult human being consumes in food from 145 to 165 grains of carbon per hour, and gives off from 12 to 16 cube feet of carbonic acid gas.

An assemblage of 1000 persons will give off in two hours, in vapor, 8.5 gallons water, and nearly as much carbon as there is in 56 lbs. of bituminous coal.

Proportion of Oxygen and Carbonic Acid at following Locations.

Pure Air represented by Oxygen 20.96.

Street in Glasgow	20.895	Metropolitan Railway (underground)	20.6
Regent Street, London	20.865	Pit of a Theatre	20.74
Centre Hyde Park	21.005	Gallery of a Theatre	20.63

Carbonic Acid .04 *Per cent.*

Open field, Manchester	.0383	Top of Monument, London	.0398
Churchyard	.0323	Hyde Park	.0334
Market, Smithfield	.0446	Metropolitan Railway (underground)	.338
Factory mills	.283	Lake of Geneva	.046
School-rooms	.097	Boys' school	.31*
Pitt of theatre, 11 P. M.	.32	Girls' "	.723†
Boxes " 12 "	.218	Horse stable	.7
Gallery " 10 "	.101	Convict prison	.045

* Roscoe. † Peltenhoffer.

Consumption of Atmospheric Air. (*Coathupe.*)

One wax candle (three in a lb.) destroys, during its combustion, as much oxygen per hour as respiration of one adult.

A lighted taper, when confined within a given volume of atmospheric air, will become extinguished as soon as it has converted 3 per cent. of given volume of air into carbonic acid.

Carbonic Acid Exhaled per Minute by a Man. (*Dr. Smith.*)

During sleep 4.99 per cent., lying down 5.91, walking at rate of 2 miles per hour 18.1, at 3 miles 25.83, hard labor 44.97.

ANIMAL POWER.

Work.

Vork is measured by product of the resistance and distance through h its point of application is moved. In performance of work by ns of mechanism, work done upon weight is equal to work done by er.

nit of Work is the *moment* or effect of 1 pound through a distance foot, and it is termed a *foot-pound.*

France a kilogrammetre is the expression, or the pressure of a nme through a distance of 1 meter = 7.233 foot-pounds.

observation upon animal power furnishes the following as maximum

to .33 of that which could be produced

r a man, and from .08 to .066 for a for a brief interval, and not involv-

from .33 to .5 for a brief interval, stained without prejudice to health yond 18 hours per day, however lim- red a constant attendance.

Men.

Mean effect of power of men working to best practicable advantage, is ɩising of 70 lbs. 1 foot high in a second, for 10 hours per day = 4200 *foot-ounds* per minute.

Windlass.—Two men, working at a windlass at right angles to each other, ɪn raise 70 lbs. more easily than one man can 30 lbs.

Labor.—A man of ordinary strength can exert a force of 30 lbs. for 10 ours in a day, with a velocity of 2.5 feet in a second = 4500 lbs. raised one ɔot in a minute = .2 of work of a horse.

A man can travel, without a load, on level ground, during 8.5 hours a day, t rate of 3.7 miles an hour, or 31.45 miles a day. He can carry 111 lbs. 1 miles in a day. Daily allowance of water, 1 gallon for all purposes; and e requires from 220 to 240 cube feet of fresh air per hour.

A porter going short distances, and returning unloaded, can carry 135 lbs. miles a day, or he can transport, in a wheelbarrow, 150 lbs. 10 miles in a ay.

Crane.—The maximum power of a man at a crane, as determined by Mr. 'ield, for constant operation, is 15 lbs., exclusive of frictional resistance, 'hich, at a velocity of 220 feet per minute = 3300 foot-pounds, and when xerted for a period of 2.5 minutes was 17.329 foot-pounds per minute.

Pile-driving.—G. B. Bruce states that, in average work at a pile-driver, a ɩborer, for 10 hours, exerts a force of 16 lbs., plus resistance of gearing, and t a velocity of 270 feet per minute, making one blow every four minutes.

Rowing.—A man rowing a boat 1 mile in 7 minutes, performs the labor f 6 fully-worked laborers at ordinary occupations of 10 hours per day.

Drawing or Pushing.—A man drawing a boat in a canal can transport 10 000 lbs. for a distance of 7 miles, and produce 156 times the effect of a ɪan weighing 154 lbs., and walking 31.25 miles in a day; and he can push n a horizontal plane 20 lbs. with a velocity of 2 feet per second for 10 hours ɩer day.

Tread-mill.—A man either inside or outside of a tread-mill can raise 30 bs. at a velocity of 1.3 feet per second for 10 hours, = 1 404 000 foot-pounds.

Pulley.—A man can raise by a single pulley 36 lbs., with a velocity of .8 f a foot per second, for 10 hours.

Walking.—A man can pass over 12.5 times the space horizontally that he ɛan vertically, and, according to J. Robison, by walking in alternate directions ɪpon a platform supported on a fulcrum in its centre, he can, weighing 16- bs., produce an effect of 3 984 000 foot-pounds. for 10 hours per day.

Pump, Crank, Bell, and Rowing.—Mr. Buchanan ascertained that, in wo ng a pump, turning a crank, ringing a bell, and rowing a boat, the effecti ɔower of a man is as the numbers 100, 167, 227, and 248.

Pumping.—A practised laborer can raise, during 10 hoı lbı vater 1 foot in height, with a properly designed and constı

Crank.—A man can exert on the handle of a screw-jac lius for a short period a force of 25 lbs., and continuou ɔower of 20 lbs. Mr. J. Field's tests gave 11.5 lbs. as easil lifficult, and 27.6 with great difficulty.

Mowing.—A man can mow an acre of grass in 1 day.

Reaping.—A man can reap an acre of wheat in 2 days.

Ploughing.—A man and horse .8 of an acre per day.

Day's Work. (*D. K. Clark.*)

Laborer.—Carrying bricks or tiles, net load 106 lbs. = 600 lbs. 1 mile.

Carrying coal in a mine, net load 95 to 115 lbs. = 342 lbs. 1 mile.

Loading coke into a wagon, net load 100 lbs. = 270 lbs. 1 mile.

Loading a boat with coal, net load 190 lbs. = 1230 lbs. 1 mile, or 20 cube yards of earth in a wagon.

Digging stubble land .055 of an acre per day, or 2000 cube feet of superficial earth.

Breaking 1.5 cube yards hard stone into 2 inch cubes.

Quarrying.—A man can quarry from 5 to 8 tons of rock per day.

A foot-soldier travels in 1 minute, in common time, 90 steps = 70 yards.

He occupies in ranks a front of 20 inches, and a depth of 13, without a knapsack; interval between the ranks is 13 inches.

Average weight of men, 150 lbs. each, and five men can stand in a space of 1 square yard.

Effective Power of Men for a Short Period.

Manner of Application.	Force.	Manner of Application.	Force.
	Lbs.		Lbs.
Bench-vice or Chisel	72	Screw-driver, one-hand	84
Drawing-knife or Auger	100	Small screw-driver	14
Hand-plane	50	Thumb and fingers	14
Hand-saw	36	Windlass or Pincers	60

The muscles of the human jaw exert a force of 534 lbs.

Mr. Smeaton estimated power of an ordinary laborer at ordinary work was equivalent to 3762 foot-pounds per minute. But, according to a particular case made by him in the pumping of water 4 feet high, by good English laborers, their power was equivalent to 3904 foot-pounds per minute; and this he assigned as twice that of ordinary persons promiscuously operated with.

Mr. J. Walker deduced from experiments that the power of an ordinary laborer, in turning a crank, was 13 lbs., at a velocity of 320 feet per minute for 8 hours per day.

Amount of Labor produced by a Man. (*Morin.*)

For 10 hours per day.

MANNER OF APPLICATION.	Power.	Velocity per Second.	Weight raised. Feet per Minute.	HP for Period gives.
	Lbs.	Feet.	Lbs.	No.
Throwing earth with a shovel, a height of 5 feet	6	1.33	480	8.7
Wheeling a loaded barrow up an inclined plane, 1 to 12	132	.625	4950	90
Raising and pitching earth in a shovel 13 feet horizontally	6	2.25	810	14.7
Pushing and drawing alternately in a vertical direction	13	2.5	1950	35.5
Transporting weight upon a barrow, and returning unloaded	132	1	7920	144
FOR 8 HOURS PER DAY.				
…ling a slight elevation, unloaded	143	.5	4290	62
…g, and pushing or drawing in a horizontal …tion	26	2	3120	45.8
… crank	18	2.5	2790	39
…-mill*	140	.5	4200	61.1
…	26	5	7800	113
…ours PER DAY.				
…'s back	88	2.5	13200	160.5
…urn-…	140	1.75	14700	160.5
…ght…	140	.2	1680	[illegible]
…	44	.5	1320	[illegible]

…ill, in an individual case, at 140 lbs., … at 1 foot per second; hence 70 ÷ 1…

;ompute Number of Men to Perform Work upon a Tread-mill or Pile-driver.

,E.—To product of weight to be raised and radius of crank, add fric' wheel, and divide sum by product of power and radius of wheel.

IPLE.—How many men are required upon a tread-mill, 20 feet in diameter, › a weight of 9233.33 lbs., crank 9 inches in length, weight of wheel and its timated at 5000 lbs., and friction at .015.
;ht of a man assumed at 25 lbs. Radius of crank .75 feet.

:t of a man on a tread-mill, page 433, 30 lbs. at a velocity of 1.3 feet per second, < 60 = 78 *feet per minute.*

33 × .75 + $\overline{5000 \times .015}$ = 7000 *lbs. resistance of load and wheel,* and 7000 ÷ $\frac{}{1416}$ × 10 × 30 = 7000 = *load and weight ÷ product of power increased by its*
over load, radius of wheel and power = 7000 ÷ $\overline{1.241 \times 10 \times 30}$ = 18.8 *men.*

Horse.

›unt of Labor produced by a Horse under different Circumstances. (*Morin.*)

For 10 *hours per day.*

MANNER OF APPLICATION.	Power.	Velocity per Second.	Weight drawn. Feet per Minute.	HP for Period given.
	Lbs.	Feet.	Lbs.	No.
ng a 4-wheeled carriage at a walk	154	3	27 720	504
oad upon his back at a walk	264	3.75	59 400	1080
›orting a loaded wagon, and returning unled at a walk	1540	2	184 800	3360
ng a loaded wagon at a walk	1540	3.75	346 500	6300
FOR 8 HOURS PER DAY.				
a revolving platform at a walk.............	100	3	18 000	260.8
FOR 4.5 HOURS PER DAY.				
a revolving platform at a trot	66	6.75	26 730	218.7
ng an unloaded 4-wheeled carriage at a trot.	97	7.25	43 195	353.5
ng a loaded 4-wheeled carriage at a trot.....	770	7.25	334 950	2741

raction power of a horse, when continuously at a walk, is equal to 120 lbs., rade of road 1 in 30, resistance on a level being one thirtieth of load, he can a load of 120 × 30 ÷ 2 = 1500 lbs.

Street Rails or Tramways. (*Henry Hughes.*)

rs, 26 lbs. per ton, or 1 to 86 as a mean.

›rformance of Horses in France. (*M. Charié-Marsaines.*)

SEASON.	Road.	Weight per Horse.	Speed per Hour.	Work per Hour, drawn One Mile.	Ratio of Pavement to Macadam
		Tons.	Miles.	Ton-miles.	
r.................	Pavement	1.306	2.05	2.677	1.644 to
	Macadam	.851	1.91	1.625	
ner	Pavement	1.395	2.17	3.027	
	Macadam	1.141	2.16	2.464	

›rage daily work of a Flemish horse in North of France, where ›ads heavy, is, on same authority, as follows:

Winter, 21.82 ton-miles per day. } Mean for the year,
Summer, 27.82 " " }

...ample = 53.8 lbs., from which a deduction is to be made for excess of ... ...formed in 8 hours over 10. Or, as 10 : 8 :: 53.8 : 43.04 lbs., which does n... ... 30 lbs. for that of an average performance.

Greatest mechanical effect of an ordinary horse is produced in operating gin or drawing a load on a railroad, when travelling at rate of 2.5 miles p[er] hour, where he can exert a tractive force of 150 lbs. for 8 hours per day.

Horse upon Turnpike Road.

At a speed of 10 miles per hour, a horse will perform 13 miles per day fo[r] 3 years. In ordinary staging, a horse will perform 15 miles per day.

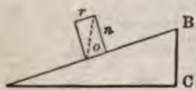
To Compute Tractive Power of a Horse Team, see Traction, page 848.

Assuming maximum load that a horse can draw on a gravel road as [a] standard, he can draw,

On best-broken stone road...............................	2 to 3 times.
On a well-made stone pavement.........................	3 to 5 "
On a stone trackway......................................	7 to 8 "
On plank road..	4 to 12 "
On a railway..	18 to 20 "

NOTE.—Track of an iron railway compared with a plank-road is as 27 to 10.

To Compute Power of Draught of a Horse at Differen[t] Elevations.



Let A B C represent an inclined plane, o weig[ht] of a horse which, being resolved into two co[m]ponent forces, one of which, n, is perpendicular [to] plane of inclination, and other, r, is parallel to i[t]. Hence, r represents force which horse must ov[er]come to move his own weight.

Then, by similar triangles, A B or l : B C or h :: o : r. Or, $\frac{h\,o}{l} = r$.

If t represents tractive power of horse, upon a level, of 100 lbs., t' tracti[ve] power upon a plane of inclination, and r that part of force exerted by h[im] which is expended upon his own body, then $t' = t - r$, or $t - \frac{h\,o}{l} = t'$ in lb[s].

ILLUSTRATION.—If inclination is 1 in 50.
Assume $t = 100$, weight of horse 900 lbs., and $l = 50.01$.

$$\text{Then, } 100 - \frac{1 \times 900}{50.01} = 100 - 17.99 = 82.01 \textit{ lbs.}$$

Assuming load that a horse can draw on a level at 100, he can draw up inclinations as follows:

1 in 100..... 91	1 in 75..... 88	1 in 50..... 82	1 in 35..... 74	1 in 20....
1 " 90..... 90	1 " 70..... 87	1 " 45..... 80	1 " 30..... 70	1 " 15....
1 " 80..... 89	1 " 60..... 85	1 " 40..... 77	1 " 25..... 64	1 " 10....

On his back a horse can carry from 220 to 390 lbs., or about 27.5 per ce[nt] of his weight.

Labor.—The work of a horse as assigned by Boulton & Watt, Tredg[old], Rennie, Beardmore, and others, ranges from 20 000 to 39 320 foot-pounds p[er] minute for 8 hours, a mean of 27 750 lbs.

A horse can travel, at a walk, 400 yards in 4.5 minutes; at a trot, i[n] minutes; and at a gallop, in 1 minute. He occupies in ranks, a front of [..] ins., and a depth of 10 feet; in a stall, from 3.5 to 4.5 feet front; and at [a] picket, 3 feet by 9; and his average weight = 1000 lbs.

Carrying a soldier and his equipments (225 lbs.) he can travel 25 mil[es] in a day of 8 hours.

A draught-horse can draw 1600 lbs. 23 miles a day, weight of carriag[e in]cluded.

ry work of a horse may be stated at 22 500 lbs., raised 1 foot in a or 8 hours per day.

ll, he moves at rate of 3 feet in a second. Diameter of track should not ın 25 feet.

ascertained that a horse weighing 1232 lbs. could draw a canal-boat d of 2.5 miles per hour, with a power of 108 lbs., 20 miles per day. quivalent to a work of 23 760 foot-lbs. per minute, He estimated average work of horses, strong and weak, is at the rate of 22 000 ɔer minute.

ɛsults of trials upon strength and endurance of horses at Bedford, Eng., it nined that average work of a horse = 20 000 foot-lbs. per minute. A good draw 1 ton at rate of 2.5 miles per hour, from 10 to 12 hours per day.

ɔ of conveying goods at 3 miles per hour, per horse teams being 1, expense .es will be 1.33, and so on, expense being doubled when speed is 5.125 miles

ı of a horse is equivalent to that of 5 men, and his daily allowance of uld be 4 gallons.

ıt of Labor a Horse of average Strength is capa- ɔf performing, at different Velocities, on Canal, road, and Turnpike.

Traction estimated at 83.3 *lbs.*

ıra-n of ork.	Useful Effect, drawn 1 Mile. On a Canal.	On a Rail-road.	On a Turn-pike.	Veloci-ty per Hour.	Dura-tion of Work.	Useful Effect, drawn 1 Mile. On a Canal.	On a Rail-road.	On a Turn-pike.
urs.	Tons.	Tons.	Tons.	Miles.	Hours.	Tons.	Tons.	Tons.
[.5	520	115	14	6	2	30	48	6
3	243	92	12	7	1.5	19	41	5.1
[.5	102	72	9	8	1.125	12.8	36	4.5
2.9	52	57	7.2	10	.75	6.6	28.8	3.6

abor performed by horses is greater, but they are injured by it.

: *Power* of a horse decreases as his speed is increased, and within limits ed, or up to 4 miles per hour, it decreases nearly in an inverse ratio.

For 10 *Hours per Day.*

Traction.	Miles.	Traction.	Miles.	Traction.	Miles.	Traction.
Lbs.	Per Hour.	Lbs.	Per Hour.	Lbs.	Per Hour.	Lbs.
330	1.5	165	2.25	110	3	82
250	1.75	140	2.5	100	3.5	70
200	2	125	2.75	90	4	62

For Ordinary or Short Periods. (*Molesworth.*)

per hour..........	2	3	3.5	4	4.5	5
r in lbs............	166	125	104	83	62	41

Mule. (*D. K. Clark.*)

ɔn back, 170 to 220 lbs. day's work = 6400 lbs. 1 mile; 400 lbs. at 2.9 : hour = 5300 lbs. 1 mile, and 330 lbs. at 2 miles per hour = 5000 lbs.

revolving platform, at a velocity of 3 feet per second, = 11 880 lbs. raised ɔer minute, or 172.2 HP for 8 hours per day

Ass.

ɔn back, 176 lbs. carried 19 miles day's work = 3300 lbs. 1 mile.

a an ass carries 450 to 550 lbs. grain.

revolving platform, at a velocity of 2.75 feet per second, = 5280 lbs. raised *ɪr minute, or 76.5 HP for 8 hours per day.*

Ox.

An Ox, walking at a velocity of 2 feet in a second (1.36 miles per hour), exerts a power of 154 lbs., = 18480 lbs. raised one foot per minute, or 268.8 HP for 8 hours per day.

A pair of well-conditioned bullocks in India have performed work = 8000 foot-lbs per minute.

Camel.

Load on back, 550 lbs. carried 30 miles per day for 4 days, 4 days' work 16500 lbs. 1 mile, for 5 days 13000 lbs. 1 mile = 44 HP for 10 hours per day.

Load of a Dromedary, 770 lbs.

Llama.

Load on back, 110 lbs., day's work 2000 to 3000 lbs. 1 mile = .5 to .75 P for 10 hours per day.

Birds and Insects.

Area of their wing surface is in an inverse ratio to their weight.

Assuming weight of each of the following Birds to be one pound, and each Insect one ounce, the relative area of their wing surface proportionate to that of their actual weight would be as follows (*M. De Lucy*):

	Sq. ft.		Sq. ft.		Sq. ft.		Sq. ft.
Swallow	4.85	Pigeon	1.27	Gnat	3.05	Cockchafer	.32
Sparrow	2.7	Vulture	.82	Dragon-fly, sm'll	1.83	Bee	.33
Turtle-dove	2.13	Crane, Australia	.41	Lady-bird	1.66	Meat-fly	.35

Crocodile and Dog.

The direct power of their jaws is estimated at 120 lbs. for the former and 44 for the latter, which, with the leverage, will give respectively 6000 and 1500 lbs.

PERFORMANCES OF MEN, HORSES, ETC.

Following are designed to furnish an authentic summary of the fastest or most successful *recorded* performances in each of the feats, etc., given.

MAN. Walking.

1874, *Wm. Perkins*, London, Eng., .5 mile, in 2 *min.* 56 *sec.*; 1, in 6 *min.* 23 *sec.*; 1877, 20, in 2 *hours* 39 *min.* 57 *sec.*

1881, *C. A. Harriman*, Chicago, Ill., 530 miles, in 5 *days* 20 *hours* 47 *min.*

1878, *W. Howes*, London, Eng., 50 miles, in 7 *hours* 57 *min.* 44 *sec.*; 1880, 57 miles, in 13 *hours* 7 *min.* 27 *sec.*, and 100, in 18 *hours* 8 *min.* 15 *sec.*

1801, *Capt. R. Barclay*, Eng., country road, 90 miles, in 20 *hours* 22 *min.* 4 *sec.*, including rests; 1803, .25 mile, in 56 *sec.*, and Charing Cross to Newmarket, 64, in 10 *hours*, including rests; 1806, 100, in 19 *hours*, including 1 *hour* 30 *min.* in rests, 1809, 1000, in 1000 consecutive *hours*, walking a mile only at commencement of each hour.

1877, *D. O'Leary*, London, Eng., 200 miles, in 45 *hours* 21 *min.* 33 *sec.*

1818, *Jos. Eaton*, Stowmarket, Eng., 4032 quarter miles, in 4032 consecutive *quarter hours.*

1877, *Wm. Gale*, London, Eng., 1500 miles, in 1000 consecutive *hours*, 1.5 miles 1 *hour*; and 4000 quarter miles, in 4000 consecutive periods of 10 *minutes.*

- *Chas. Rowell*, New York, N.Y., and running, 89 miles 1640 yards, in 12 *hours*.

Geo. Hazael, New York, N. Y., and running, 600 miles 220 yards, in 6 *days*.

J. W. Raby, London, Eng., 2 miles in 13 *min.* 14 *sec.*; 3, in 20 *min.* 21.5 *sec.*; *min.* 28 *sec.*: 5, in 35 *min.* 10 *sec.*; and 10, in 1 *hour* 14 *min.* 45 *sec.*

New York, N. Y., 8 miles in 58 *min.* 37 *sec.*

., 25 miles in 3 *hours* 35 *min.* 14 *sec.*

ondon, Eng., 10 miles in 51 *min.* 6.6 *sec.*

ingham, Eng., 40 miles in 4 *hours* 46 *min.* 54 *sec.*

oklyn, N. Y., 50 miles in 7 *hours* 29 *min.* 47 *sec.*

Running.

. S., Manchester, Eng., flying start, 100 yards, in 5.25 *sec.*

ester, Eng., 600 yards, in 1 min. 13 sec.

rk, N. Y., 1000 yards, in 2 min. 13 sec.

ket, Eng., 1 mile, in 4 min. 2 sec., descending grou

5 sec.; 1865, 11 miles 1660 yards, in 1 hour 2 min. 2.5

1852, *Wm. Howitt*, "American Deer," London, Eng., 15 miles in 1 *hour* 22 *min.*
1863, *L. Bennett*, "Deerfoot," Hackney Wick, Eng., 12 m., in 1 *hour* 2 *min.* 2.5 *sec.*
1879, *Patrick Byrnes*, Halifax, N. S., 20 miles, in 1 *hour* 54 *min.*
1880, *D. Donovan*, Providence, R. I., 40 miles, in 4 *hours* 48 *min.* 22 *sec.*
17—, *A Courier*, East Indies, 102 miles, in 24 *hours.*
1889, *H. M. Johnson*, Denver, Col., 50 yards, in 5 *sec.*
1884, *M. K. Kittleman*, Oakland. Cal., 150 yards (twice), in 14 *min.* 6 *sec.*
1890, *James Grant*, Cambridge, Mass., 5 miles in 25 *min.* 22.25 *sec.*

Jumping, Leaping, etc.

1854, *J. Howard*, Chester, Eng., 1 jump, board raised 4 ins. in front, running start, ith dumb-bells, 5 lbs., 29 *feet* 7 *ins.*

1868, *Geo. M. Kelley*, Corinth, Mass., running, and from a spring board, leaped rer 17 horses standing side by side.

1879, *G. W. Hamilton*, Romeo, Mich., dumb-bells, 22 lbs., standing jump, 14 *feet* 5 *ins.*

1886, *J. Purcell*, Dublin, running long jump, 23 *feet* 11.5 *ins.*

1889, *J. Darby*, Ashton-under-Lyne, Eng., two standing jumps, with weights, 26 *:et* 8.5 *ins.*

H. M. Johnson, St. Louis, Mo., without weights, 22 *feet* 6.75 *ins.* 10 standing long ımps, without weights, 114 *feet* 8.5 *ins.*

J. F. Kearny, Walpole, Mass., 3 standing long jumps, with weights, 42 *feet* 3 *ins.;* ithout weights, at Boston, Mass., 35 *feet* 6 *ins.* Boston, Mass., running high jump, ith weights, 6 *feet* 5.25 *ins.;* backward jump, with weights, heel to toe, 12 *feet* 1.25 *ıs.* Oak Island, Mass., standing high leap, with weights, 5 *feet* 9.5 *ins.*

Lifting.

1825, *Thomas Gardner*, of New Brunswick, N. S., a barrel of pork, 320 *lbs.*, under ach arm; also transported across a pier an anchor, 1200 *lbs.*

1868, *Wm. B. Curtis*, New York, N. Y., 3239 *lbs.*, in harness.

1883, *D. L. Dowd*, Springfield, Mass., by hands, 1442.25 *lbs.*

Throwing Weights.

1870, *D. Dinnie*, New York, N. Y., *light stone*, 18 lbs., 43 *feet; heavy stone*, 24 lbs., 4 *feet* 6 *ins.; heavy hammer*, 24 lbs., 83 *feet* 8 *ins.;* 1872, Aberdeen, Scotland, *light ammer*, 138 *feet;* run, 16 lbs., 162 *feet.*

1887, *Peter Foley*, Milwaukee, Wis., 56 lbs., without follow, 31 *feet* 5 *ins.*

Swimming.

1835, *S. Bruck*, 15 miles, in rough sea, in 7 *hours* 30 *min.*
1846, *A Native*, off Sandwich Islands, 7 miles at sea, with a live pig under one arm.
1870, *Pauline Rohn*, Milwaukee, Wis., 650 feet, still water, in 2 *min.* 43 *sec.*
1872, *J. B. Johnson*, London, Eng., remained under water 3 *min.* 35 *sec.*
1875, *Capt. M. Webb*, Dover, Eng., to Calais, France, 23 miles, crossing two full nd two half tides = 35 miles, in 21 *hours* 45 *min.* 1880, Afloat 60 *hours.*
1886, *J. Haggerty*, Blackburn Baths, Eng., 100 yards, 4 turns, in 1 *min.* 5.5 *sec.*
1890, *J. Nuttall*, London, Eng., 1000 yards, 23 turns, in 13 *min.* 54.5 *sec.*
1885, *J. J. Collier*, London, Eng., 1 mile in 26 *min.* 52 *sec.*

Skating.

1877, *John Ennis*, Chicago, Ill., 9 laps to a mile, 100 miles, in 11 *hours* 37 *min.* 45 *ec.;* and 145 inside of 19 hours.
1887, *T. Donoghue, Jun.*, Newburgh, N. Y., 1 mile, with wind, in 2 *min.* 12.375 *sec.*
1882, *S. J. Montgomery*, New York, N. Y., 50 miles, in 4 *hours* 14 *min.* 36 *sec.*

NOTE.—The *Sporting Magazine*, London, vol. ix., page 135, reports a man in 1767 to have skated a nile upon the Serpentine, Hyde Park, London, in 57 seconds.

HORSE. Trotting.

1878, "Controller," San Francisco, Cal., 10 miles, harness, in 27 *min*, 27.25 *sec.*, and 20 miles, wagon. in 58 *min.* 57 *sec.*
1875, "Steel Grey," Yorkshire, Eng., 10 miles, saddle, in 27 *min.* 56.5 *sec*
1867, "John Stewart," Boston, Mass., half-mile track, 20 miles, harne *min.* 5.75 *sec.*, and 20.5 miles in 59 *min.* 31 *sec.*
1830, "Top Gallant," Philadelphia, Penn., 12 miles, harness, in 38 *min.*
1829, "Tom Thumb," Sunbury Common, Eng., 16.5 miles, harness, 48 *min.* 45 *sec.;* and 100 miles, in 10 *hours* 7 *min.*, including 37 min. in rest.
1869, "*Morning Star,*" *Doncaster*, Eng., 18 miles, harness (sulky 100 *min.* 27 *sec.*
1835, "*Black Joke,*" *Providence*, R. I., 50 miles, saddle, 175 lbs., in 3 hou

1855, "Spangle," Long Island, N. Y., 50 miles, wagon and driver 400 l
hours 59 *min.* 4 *sec.*
1837, "Mischief," Jersey City, N. J., to Philadelphia, Penn., 84.25 miles, very hot day and sandy road, in 8 *hours* 30 *min.*
1853, "Conqueror," Long Island, N. Y., 100 miles, harness, in 8 *hours* 5
sec., including 15 short rests.
1873, *M. Delaney's* mare, St. Paul's, Minn., 200 miles, race track, harne
hours 20 *min.*, including 15 *hours* 49 *min.* in rests.
1834, "Master Burke" and "Robin," Long Island, N. Y., 100 miles, wag
hours, 17 *min.* 22 *sec.*, including 28 *min.* 34 *sec.* in rests.

Stage-coaching.

1750, *By the Duke of Queensberry*, Newmarket, Eng., 19 miles, in 53 *min.*
1830, *London to Birmingham, Eng.*, "Tally-ho," 109 miles, in 7 *hours* including stop for breakfast of passengers.

Leaping.*

1821, A horse of Mr. Mane, at Loughborough, Leicestershire, Eng., 173 lb
hedge 6 *feet* in height, 35 *feet.*
1821, A horse of Lieut. Green, Third Dragoon Guards, at Inchinnan, Eng
by a heavy dragoon, over a wall 6 *feet* in height and 1 *foot* in width at top.
1839, "Lottery," Liverpool, Eng., over a wall, 33 *feet.*
1847, "Chandler," Warwick, Eng., over water, 37 *feet.*

NOTE.—The maximum stride of a horse is estimated to be 28 *feet* 9 *ins.*; "Eclipse" has
feet. The maximum stride of an elk is 34 *feet*, and of an elephant 14 *feet.*

Running.

1701, *Mr. Sinclair*, on the Swift at Carlisle, a gelding, 1000 miles, in 1000
tive *hours.*
1731, *Geo. Osbaldeston*, Newmarket, 156 lbs., 100 miles, by 16 horses, in 4
min. 40 *sec.*, and 200, by 28 horses, in 8 *hours* 39 *min.*, including 1 *hour* 2 *mi*
in rests; 1 horse, "Tranby," 16 miles, in 33 *min.* 15 *sec.*
1752, *Spedding's* mare, 100 miles, in 12 *hours* 30 *min.*, for 2 consecutive
1754, A Galloway mare of Daniel Corker's, Newmarket, 300 miles, by o
67 lbs., in 64 *hours* 20 *min.*
1761, *John Woodcock*, Newmarket, 100 miles per day, by 14 horses, one
for 29 consecutive days.
1814, *An Officer of 14th Dragoons*, Blackwater, 12 miles, 1 horse, in 25 *mi*
1868, *N. H. Mowry*, San Francisco, Cal., race track, 160 lbs., 300 miles, by
(Mexican), in 14 *hours* 9 *min.*, including 40 minutes for rests; the first
hours 2 *min.* 48 *sec.*, and the fastest mile in 2 *min.* 8 *sec.*
1869, *Nell Coher*, San Pedro, Texas, 61 miles, in 2 *hours* 55 *min.* 15 *sec.*,
rests.
1870, *John Faylor*, Carson City, Nevada, 50 miles, by 18 horses, in 1 *hou*
33 *sec.*; and Omaha, Neb., 56 miles, in 2 *hours* 26 *min.*, including rests.
1876, *John Murphy*, New York, N. Y., 155 miles, by 20 horses, in 6 *hour*
7 *sec.*
1878, *Capt. Salvi*, Bergamo to Naples, Italy, 580 miles, in 10 *days.*
1880, "Mr. Brown," Rancocas, N. J., *aged*, 160 lbs., 10 miles, in 26 *min.* 1
1828, "Chapeau de Paille" (*Arabian*), India, 1.5 miles, 115 lbs., in 2 *min.*
183–, *Capt. Horne* (*Arabians*), Madras to Bungalore, India, 200 miles, in
10 *hours.*

DOGS. Coursing and Chasing.

yhound and Hare ran 12 miles in 30 *min.*
Fox, at Brende, Eng., ran 50 miles in 6.5 *hours.*
und, at Bushy Park, Eng., leaped over a brook 30 *feet* 6 *ins.*

BIRDS. Flying.

oose and Swallow, 90 miles; *Crow*, 25 miles
h to Cologne, Germany, 600 miles, in 8 *hours.*
se Lake to Paterson, N. J., 3 miles, in 3 *min.*

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feet in height.—Sporting Magazine, London, vol. xl.

HORSE-POWER.

Horse-power.—IP is the principal measure of rate at which work is performed. One horse-power is computed to be equivalent to raising of 33 000 lbs. one foot high per minute, or 550 lbs. per second. Or, 33 000 foot-lbs. of work, and it is designated as being Nominal, Indicated, or Actual.

A IP in work is estimated at 33 000 lbs., raised 1 foot in a minute; but as a horse can exert that force for only 6 hours per day, one work IP is equivalent to that of 4.5 horses, at a rate of 3 miles per hour.

Cheval-vapeur of France is computed to be equivalent to 75 kilogrammeters of work per second, or 7.233 foot-lbs., or $75 \times 7.233 = 542.5$ foot-lbs., which is 1.37 per cent. less than American or English value.

BELTS AND BELTING.

Capacity of belts to transmit power is determined by extent of their adhesion to surface of pulley, and it is very limited in comparison with tensile strength of belt.

Resistance of a belt to slipping depends essentially upon character of surface of pulley, its degree of tension, and width, and as adhesion is in proportion to pressure on surface of pulley, long belts, by having greater weight, give greater adhesion.

Tensile strength of Belting per square inch of section ranges as follows:

Tanned Leather, .186 inch thick, from 2846 to 5000 lbs., or from 530 to 930 lbs. per inch of width; when *spliced* 385 lbs., and when *laced* 210 lbs.

Taking .3 as a factor of safety, 70 and 128 lbs. represent resistance per sq. inch that belts in operation may be subjected to, and they have been run successfully at these tensions.

Raw hide has a tensile strength of 1.5 times that of tanned.

By Experiments of H. R. Towne and Mr. Kirkaldy. (England.)

Tensile strength of Single leather belting per square inch of section.

Laced, 960 *lbs.* Riveted, 1740 *lbs.* Solid, 3080 *lbs.*

Norris & Co.—Double, 2 ins., 2942 *lbs.*; 6 ins., 5603 *lbs.*; 12 ins., 14 861 *lbs.* Single, 3.5 ins., 3007 *lbs.*; 5 ins., 4060 *lbs.*; 10 ins., 8846 *lbs.*

Spill's belting, from flax, saturated with an endurable substance, gave tensile strength per inch of width as follows:

No. 1, 5 ins. wide, 1254 *lbs.* No. 2, 5 ins. wide, 1489 *lbs.* No. 3, 10 ins. wide, 1663 *lbs.*

At a velocity of 1000 feet per minute, a width of leather belt of 1 inch will transmit power of 1 horse, and at a velocity of 1800 feet, .56 of an inch will transmit a like power, pulley being fully three feet in diameter, equal to a stress of 33 lbs. per inch of width of belt of ordinary thickness.

To Compute Width of a Leather Belt.

Assuming a well-defined case (where limit of adhesion was ascertained), a belt of ordinary construction (laced), and 9 inches in width, transmitted the power of 15 horses over a pulley 4 feet in diameter, at a velocity of 1800 feet per minute, with an arc of adhesion of 210°, or of .6 or 7.54 feet of circumference, and with an area of 95 square feet of belt per IP.

Hence, $\frac{4400 \text{ to } 5000 \text{ IP}}{d\,v} = w$; *w representing width of b[illegible] di-ameter of pulley in feet, and v velocity of belt in feet per m[illegible]*

NOTE.—*Thickness of belt* should be added to diameter of pul[illegible] *-lements to the formulas of 13* different authors, the result var[illegible] *-ts, mean of which is 10.675.* For double belting width = .6 [illegible]

ILLUSTRATION.—If IP 25, diameter of pulley 4 feet, and velocity 2250 feet; v should be width of belt?

$$\frac{4500 \times 25}{4 \times 2250} = 12.5 \textit{ ins. for ordinary thickness of } .1875 \textit{ in.}$$

To Compute Elements of Belting.

$$\frac{v\,w}{1000} = \text{IP}; \quad \frac{\text{IP}\,33\,000}{v\,w} = \text{P}; \quad \frac{33\,000\,\text{IP}}{v} = \text{W}; \quad \frac{\text{W}}{t} = \text{S}; \quad \frac{\text{A} - a}{l\,t}$$

P *representing power or stress transmitted,* W *weight or stress on* *t thickness of belt,* S *stress on belt per inch of width,* A *and* a *areas of* *and eye, and* l *length in feet.*

NOTE.—70 square feet of good belting are capable of transmitting an indicate

India Rubber Belting. (*Vulcanized.*)

Results of Experiments upon Adhesion of India Rubber and Leather Belting (*J. H. Cheever*).

Rubber.	Lbs.	*Leather.*
Rubber belt slipped on iron pulley at	90	Leather belt slipped on iron pulley
" " leather "	128	" " leather "
" " rubber "	183	" " rubber "

Hence it appears that a Rubber Belt for equal resistances with a Leathe may be reduced respectively 46, 50, and 30 per cent.

Iron Wire.—A wire rope .375 inch in diameter, over a pulley 4 fe diameter, and running at a velocity of 1250 feet per minute, will tra 4.5 IP.

Diameter of pulley should not be less than 140 times diameter of rope, in to avoid undue bending of wires.

A sheet-iron belt 7 inches in width proved more effective than one of leat like width.

General Notes.

Leather Belts—Are best when oak tanned, should be frequently oiled,* and run with hair side over pulley will give greatest adhesion.

Ordinary thickness .1875 inch, and weight 60 lbs. per cube foot.

Relative effect of different pulleys and belts:

Pulleys.—Leather surface......	1.	Turned iron....................	
Rough iron..........	.41	Turned wood..................	

Tensile strength of calf and sheep skins is about one half that of beeve and

Morin assigns 50 lbs. as a proper stress per inch of width of good belting.

Presence of small holes in a belt will prevent its slipping or squealing.

Rubber Belts.—Best vulcanized rubber is stronger than leather, and its resi is from 50 to 85 per cent. greater.

To increase adhesion, coat driving surface with boiled oil or cold tallow, an apply powdered chalk.

When new, cut them .1875 inch short for each foot in length required, to of the stretch that occurs in their early operation.

They should be kept free from contact with an animal oil.

Three ply, .1875 inch thick, has a tensile resistance of 600 lbs. per inch of v

Relative slipping of a vulcanized belt, over smooth or turned leather or r faced iron pulleys is as .5, .7, and 1.

Rubber, Gutta percha, and Canvas belts will stretch continuously.

Memoranda.

..d be set as near horizontal as practicable, in order that the sag ..n on pulley, and hence power should be communicated th

..med by belts is about 2 per cent., hence, to main ..ver must be increased in diameter pro rata wi

*..., etc., page 871, for compositions, etc.

A belt, 11 ins. in width, over a driver 4 feet in diameter, running from 1200 to 225 feet per minute, will transmit the power from two steam cylinders, 6 ins. in diameter and 11 ins. stroke, averaging 125 revolutions per minute, with a pressure of 50 lbs. per sq. inch.

A double belt, 75 ins. in width and 153.5 feet in length, transmitted 650 IHP.

Pulleys should have a slight convexity of surface. Authorities differ, from .5 inch per foot of breadth to .1 of breadth. Belts run at a high speed are less liable to slip than at low speed.

The best speeds for economy are from 1200 to 1500 feet per minute, and the best for result not to exceed 1800.

Belts.—Leather, hair-side.... 1 | Leather, flesh-side... .74 | Rubber...... .5
Gutta percha .... .44 | Canvas .... .35

Coefficient of Friction of a Belt in operation is assumed to be .423.

Smooth surface belts are most endurable and soft most adherent.

Round belts .25 and .5 inch in diameter are fully equal in operation to flat of and 3 ins., and grooves in their pulleys should be angular or V shaped.

The neutral point of a rope belt is at .33 of diameter from inside surface.

Friction of driving and pulley bearings is about .025.

A fan-blower No. 6*, driven by a belt 3.875 ins. in width and .18 in thickness, a velocity of 2820 revolutions per minute, requires power of 9.7 horses.

Area of belts per IP varies essentially, ranging from 25 to 100 square feet; the mean is 75.

BLASTING.

In Blasting, rock requires from .25 to 1.5 lbs. gunpowder per cube yard, according to its degree of hardness and position. In small blasts 2 cube yards have been rent and loosened, and in very large blasts 2 to 4 cube yards have been rent and loosened, by 1 lb. of powder.

Tunnels and shafts require 1.5 to 2 lbs. per cube yard of rock.

Gunpowder has an explosive force varying from 40000 to 9000 lbs. per sq. inch. That used for blasting is much inferior to that used for projectiles, the proportion being fully one third less.

Nitro-glycerine is an unctuous liquid, which explodes by concussion an extreme pressure (2000 lbs. per sq. inch), or a temperature exceeding 600° if quickly applied to it; it will inflame, however, and burn gradually.

At a temperature below 40° it solidifies in crystals.

Its explosion is so instantaneous that in rock-blasting tamping is not necessary; its explosive power by weight is from 4 to 5 times that of gunpowder.

Dynamite is nitro-glycerine 75 parts, absorbed in 25 parts of a siliceous earth termed kieselguhr: it also explodes so instantaneously as to render tamping in blasting quite unnecessary.

It is insoluble in water, and may be used in wet holes; it congeals at 40° is rendered ineffective at 212°, and has an explosive force by weight of times that of gunpowder, and by bulk 4.25 times.

Gun-cotton is insoluble in water, and has an explosive force by weight of from 2.75 to 3 times that of gunpowder, and by bulk 2.5 times. It may be detonated in a wet state with a small quantity of dry material.

Tonite is nitrated gun-cotton, and is known also as *cotton powder*. It is produced in a granulated form.

Litho-fracteur is a nitro-glycerine compound in which the base or absorbent material is made explosive by the of nitrate of baryta and charcoal.

* *For a table of Belts for Fan-blowers, etc., see* J. H. Cooper, in "Jour. Fr.

Cellulose Dynamite is when gun-cotton is used as the absorbent for nitro-glycerine; it will explode frozen dynamite, and is more sensitive to percussion than it.

To Compute Charge of Gunpowder for Rock Blasting.

RULE.—Divide cube of line of least resistance by 25, as for limestone, to 32 for granite, and quotient will give charge of powder in lbs.

$$\text{Or, } L^3 \div 32 = lbs.$$

EXAMPLE.—When line of least resistance is 6 feet, what is charge required?

$$6^3 \div 32 = 6.75 \; lbs.$$

Line of least resistance should not exceed .5 depth of hole.

Tamping.—Dried clay is the most effective of all materials for tamping; *Broken Brick* the next, and *Loose Sand* the least.

Relative Costs of a Tunnel and Shaft in England. (*Sir John Burgoyne.*)

Iron and steel	8.98	Powder	29.04
Smiths and coal	6	Labor	48.8
Fuses	7.18		100

Weight of Explosive Materials in Holes of Different Diameters.

Per Inch of Length.

Diam.	Powder or Gun-cotton.	Dynamite.	Diam.	Powder or Gun-cotton.	Dynamite.	Diam.	Powder or Gun-cotton.	Dynamite.
Ins.	Oz.	Oz.	Ins.	Oz.	Oz.	Ins.	Oz.	Oz.
1	.419	.67	1.75	1.283	2.053	2.5	2.618	4.189
1.25	.654	1.046	2	1.675	2.68	2.75	3.166	5.066
1.5	.942	1.507	2.25	2.12	3.392	3	3.769	6.03

Boring Holes in Granite.

Diam. of Jumper.	Depth of Hole.	Men.	Depth bored per Day.	Hammer.	Diam. of Jumper.	Depth of Hole.	Men.	Depth bored per Day.	Hammer.
Ins.	Ins.	No.	Feet.	Lbs.	Ins.	Ins.	No.	Feet.	Lbs.
1	1 to 2	1	8	6	2.25	5 to 10	3	6	15
1.75	2.5 to 6	3	12	14	2.5	9 to 12	3	5	16
2	4 to 7	3	8	14	3	9 to 15	3	4	18

Drill.—Width of bit compared to stock .625.

Charges of Powder.

Usual practice of charging to one third depth of hole is erroneous, inasmuch as volume of charge increases as square of diameter of hole. Hence holes of 1.5 and 2 inches, although of equal depths, would require charges in proportion of 2.25 and 4.

Line of least resistance.	Powder.	Line of least resistance.	Powder.	Line of least resistance.	Powder.	Line of least resistance.	Powder.
Feet.	Oz.	Feet.	Lbs. Oz.	Feet.	Lbs. Oz.	Feet.	Lbs. Oz.
[illegible]	.75	3	13.5	5	3 14.5	7	10 11.5
	4	4	2	6	6 12	8	16

Effects.

...der.—From its gradual combustion, rends and projects rather than

... diameter and 19 feet 7 ins. in depth, filled to 8 feet 10 ins. with ... red and rent 1200 cube yards, equal to 2400 tons. The ... men for 14 days.

...losion 4000°.

...f its combustion, shatters.

... of its combustion over gun-cotton, is ...

Drilling.

Churn-drilling.—A churn-driller will drill, in ordinary hard rock, from 8 to 12 feet, 2 inch holes of 2.5 feet depth, per day, and at a cost of from 12 to 18 cents per foot, on a basis of ordinary labor at $1 per day. Drillers receiving $2.50.

One man can bore, with a bit 1 inch in diameter, from 50 to 100 inches per day of 10 hours in granite, or 300 to 400 inches per day in limestone.

Tamping.—Two strikers and a holder can bore, with a bit 2 inches in diameter, 10 feet in a day in rock of medium hardness.

Composition for waterproof charger or fuse consists by weight of Pitch, 8 parts; Beeswax and Tallow each 1 part.

Mining. (*Lefroy's Handbook.*)

In demolition of walls line of least resistance L = half thickness, and C is a coefficient depending on structure.

Charge in lbs. $= C \times L^3$.

In a wall without counterforts, where interval between the charge is 2 L, C = .15.

In a wall with counterforts the charge to be placed in centre of each counterfort at junction with wall, C = .2.

Where the charge is placed under a foundation, having equal support on both sides, C = .4.

A leather bag, containing 50 to 60 lbs. powder, hung or supported against a gate or like barrier, will demolish it.

For ordinary mines in average rock charge in ounces $= L^3 \div 160$.

BLOWING ENGINES.

For Smelting.

Volume of oxygen in air is different at different temperatures. Thus, dry air at 85°. contains 10 per cent. less oxygen than when it is at temperature of 32°; and when it is saturated with vapor, it contains 12 per cent. less. If an average supply of 1500 cube feet per minute is required in winter, 1650 feet will be required in summer.

Smelting of Iron Ore.

Coke or Anthracite Coal.—18 to 20 tons of air are required for each ton of Pig Iron, and with *Charcoal* 17 to 18 tons are required.

(1 ton of air at 34° = 29 751, and at 60° = 31 366 *cube feet.*)

Pressure.—Pressure ordinarily required for smelting purposes is equal to a column of mercury from 3 to 10 inches, or a pressure of 1.5 to 5 lbs. per square inch.

Reservoir.—Capacity of it, if dry, should be 15 to 20 times that of cylinder if single acting, and 10 times if double acting.

Pipes.—Their area, leading to reservoir, should be .2 that of blast cylind[er] and velocity of the air should not exceed 35 feet per second.

A smith's forge requires 150 cube feet of air per minut[e] ... blast .25 to 2 lbs. per square inch. A ton of iron melted [in a cu]pola requires 3500 cube feet of air per minute. A fine[ry] ... 000 000 cube feet of air for each ton of iron refined. ... [req]uires 20 cube feet per minute for each cube yard capacit[y]

A Ton of Pig Iron requires for its reduction from th[e] ... [f]eet *of air, or 5.3 cube feet* of air for each pound of ... [p]*ressure, .7 lb. per square inch.*

To Compute Power Required to Drive a Blowing Engine.

$$\frac{.0000509}{c} V^3 \left(\frac{L}{d^5} + \frac{42}{d'^4}\right) 60 \div 33000 = \text{IP}.$$

$d' = \sqrt{\dfrac{V}{.93 \times .7854 \times v}}$. *v representing velocity of air in feet per second, d and d′ diameters of pipe and of nozzle in feet,* $= \sqrt{\dfrac{35}{.93 \times .7854 \times 500}} = .309$.

ILLUSTRATION.—What should be power of a steam-engine to drive 35 cube feet of air at a velocity of 500 feet per second, through a pipe 1 foot in diameter and 300 feet in length?

c = ratio between power employed and effect produced by it = in a well-constructed engine .5, *and* C = .93. *d* = .2974, assumed at .3.

$$\frac{.0000509}{.5} \times 35^3 \left(\frac{300}{1^5} + \frac{42}{.3^4}\right) 60 \div 33000 = 22631.625 \times 60 \div 33000 = 41.15 \text{ IP}.$$

To Compute Required Power of a Blowing Engine.

$\dfrac{P + f \times a\,v}{33000} = \text{IP}$. P *representing pressure of blast in lbs. per sq. inch; a area of cylinder in sq. ins.; v velocity of piston in feet per minute; f friction of piston and from curvatures, etc., estimated at* 1.25 *per sq. inch of piston.*

NOTE.—If cylinder is single acting, divide result by 2.

ILLUSTRATION.—Assume area of blast cylinder 5600 sq. ins., pressure of blast 2.25 lbs. per sq. inch, and velocity of piston 96 feet per second.

$\dfrac{2.25 + 1.25 \times 5600 \times 96}{33000} = \dfrac{1881600}{33000} = 57$ *horses*, the exact power developed in this case.

To Compute Dimensions of a Driving Engine.

RULE 1.—Divide power in lbs. by product of mean effective pressure upon piston of steam cylinder in lbs. per sq. inch, and velocity of piston in feet per minute, and quotient will give area of cylinder in sq. ins.

2.—Divide velocity of piston by twice number of revolutions, and quotient will give stroke of piston in feet.

Volume of air at atmospheric density delivered into reservoir, in consequence of escape through valves, and partial vacuum necessary to produce a current, will be about .2 less than capacity of cylinder.

EXAMPLE.—Assume elements of preceding case, with a pressure of 50 lbs. steam, cut off at .375, and with 12 revolutions of engine per minute, what should be area of cy[illegible] of a non-condensing engine?

[illegible]e pressure of steam with 5 per cent. clearance = 50 lbs., and 50 − [illegible] − 2.5 + 3.33 + 14.7 = 29.47 *lbs.*, and velocity of piston = 192 *feet*.

[illegible] 1.25 × 96 / [illegible] 192 = $\dfrac{1881600}{5658}$ = 332.5 sq. ins., and $\dfrac{192}{12 \times 2}$ = 8 *feet stroke*.

[illegible] was 324 sq. ins.

[illegible]ally of air, see Heat, page 521.

[illegible]condensing engine, page 733.

To Compute Elements of a Blowing Engine.

Single Stroke.

$$\frac{V\,\overline{P+f}}{230} \text{ or } \frac{A\,s\,n\,\overline{P+f}}{33\,000} = \text{IP}; \quad \frac{\sqrt{V+10\,L}}{3} = d; \quad \frac{D^2\,s\,n}{40\,a} = v;$$

$$\frac{D^2\,s\,n}{40\,v} = a; \quad \frac{230\,\text{IP}}{P+f} = V; \quad \frac{D^2\,s\,n}{92} = V; \text{ and } 34\,P + 32 = t.$$

V *representing volume of air in cube feet per minute,* P *pressure of air and frictional resistance in lbs. per sq. inch,* A *area of cylinder and a area of its valves in sq. ins., s stroke of piston in feet, n number of single strokes of piston per minute,* L *length of air-pipe from reservoir to discharge in feet, diameter of air or blast pipe and* D *diameter of cylinder in ins., v velocity of blast in feet per second, and t temperature of blast consequent upon compression in degrees.*

ILLUSTRATIONS. — Assume blowing cylinder 50 ins. in diam., stroke of piston 10 feet, number of single strokes 10 per minute, pressure by mercurial manometer 12 ins., frictional resistance .4 lb., length of pipe 25.25 feet, and area of valves 95 sq. ins.

$V = 1363.54$ *cube feet,* $P = 3$ *lbs.,* $A = 1963.5$ *sq. ins.*

Then $\frac{1363.54 \times \overline{3+.4}}{230} = 20.16$ IP, and $\frac{1963.5 \times 10 \times 10 \times \overline{3+.4}}{33\,000} = 20.23$ IP.

$$\frac{\sqrt{1363.54 + 10 \times 25.25}}{3} = 13.4 \textit{ ins.} \quad \frac{50^2 \times 10 \times 10}{40 \times 95} = 65.8 \textit{ feet.} \quad \frac{50^2 \times 10 \times 10}{40 \times 65.8} = 95 \textit{ sq. ins.}$$

To Compute Volume of Air transmitted by an Engine.

When Pressure, Temperature, etc., are given.

$$4.5\sqrt{h\left(\frac{1+.004\,t}{h+H}\right)}\,C = v. \quad \text{Then } a\,v \times 60 = V \textit{ in cube feet per minute.}$$

H *and h representing height of barometer and pressure of blast in ins. of mercury; t temperature of blast; and v velocity in feet per second.*

ILLUSTRATION.—A furnace having 2 tuyeres of 5 ins. diameter, pressure and temperature of blast 3 ins. and 350°, and barometer 30 ins.; what is volume of air transmitted per minute?

C for a conical opening $= .94$.

$$34.5\sqrt{3\left(\frac{1+.004 \times 350^\circ}{3+30}\right)} \times .94 = 34.5\sqrt{3\left(\frac{2.4}{33}\right)} = 34.5 \times .467 \times .94 = 15.14$$

feet velocity per second.

Then, area 5 ins. $= 19.635$, which $\times 2 = 39.27$ ins., and $39.27 \times 15.14 \times 60 \div 144 = 247.73$ *cube feet.*

To Compute Pressure of Blast from Water or Mercurial Gauge.

RULE.—Divide Water and Mercurial Gauge in ins. by 27.67 and 2.04 respectively, and quotient will give pressure in lbs. per sq. in

Fan-blowers.

Proportions of Parts. Blades.—Their width and lengt[h] [e]qual to .4 or .5 radius of fan.

Openings.—Inlet should be equal to radius of fan; [disch]*arge, should* be in depth not less than .125 diameter, [in] *width of fan.*

[Ecc]entricity.—.1 of diameter of fan. Journals, 4 diame[ters]

By the experiments of Mr. Buckle, he deduced

1. That velocity of periphery of blades should be .9 that of their theoretical velocity; that is, velocity a body would acquire in falling height of a homogeneous column of air equivalent to required density.

2. That a diminution of inlet from proportions here given involved a greater expenditure of power to produce same density.

3. That greater the depth of blade, greater the density of air produced with same number of revolutions.

To Compute Elements of a Fan-blower.

$\left(\frac{v}{8.02}\right)^2 \div 939.45 = d$; $244\sqrt{d} = v$; $\frac{a\,v\,60}{160} = V$; and $\frac{d\,a\,v}{400} = \text{IP}$.

v representing velocity of periphery of fan in feet per second, d inches of mercury, V *volume of air in cube feet, and a area of discharge in sq. ins.*

ILLUSTRATION.—Assume velocity of periphery of fan 123 feet per second, density of blast .25 inch, volume of air 1845 cube feet, and area of discharge 40 sq. ins.

$\overline{123 \div 8.02}^{\,2} \div 939.454 = .25$ *inch.* $244\sqrt{.25} = 122$ *feet.* $\frac{40 \times 123 \times 60}{160} = 1845$ *cub. ft.*

$\frac{.242 \times 40 \times 123}{400} = 2.97$ IP, *independent of friction of blast in pipes and tuyeres.*

To Compute Power of a Centrifugal Fan.

$V^2 \div 97\,300 = P$. V *representing velocity of tips of fan in feet per second.*

Memoranda.

Operation of a blower requires about 2.5 per cent. of power of attached boiler.

An increase in number of blades renders operation of fan smoother, but ...es not increase its capacity.

...ressure or density of a blast is usually measured in ins. of mercury, a ...sure of 1 lb. per sq. inch at 60° = 2.0376 ins.

...Vhen water is used, a pressure of 1 lb. = 27.671 ins.

...upola blast .8 lbs., and *Smith's forge* .25 to .3 lbs. per sq. inch.

...rdinary Eccentric Fan, 4 feet in diameter, with 5 blades 10 ins. wide ... in length, set 1.5 ins. eccentric, with an inlet opening of 17.5 ins. in ...er, and an outlet of 12 ins. square, making 870 revolutions per min... ...ll supply air to 40 tuyeres, each of 1.625 ins. in diameter, and at a ...ure per sq. inch of .5 inch of mercury.

...ordinary eccentric fan-blower, 50 ins. in diameter, running at 1000 revolutions ...inute, will give a pressure of 15 ins. of water, and require for its operation a ...er of 12 horses. Area of tuyere discharge 500 sq. ins.

... ...ndensing engine, diameter of cylinder 8 ins., stroke of piston 1 foot, pres... ... 18 lbs. (mercurial gauge), and making 100 revolutions per minute, will ... opening 2 feet by 2,500 revolutions per minute.

...lied as an exhausting draught to smoke-pipe of steamer ...o ins. by 8 feet, and evaporation was doubled over that

...volume of air discharged 75 per cent. that of ...ke equal diameter of cylinder, and ...r minute.

...083 of that of cylinder for speeds ... to .111 for higher speeds. Area ... (M. Claudel.)

By some experiments lately concluded in England with boilers of tw steamers, to determine relative effects of natural and forced draught furnaces the results were as follows (*R. J. Butler*):

Per Sq. Foot of Grate Surface.—Natural Draught, 10 to 10.87 IHP; *Steam Blast*, 12.5 to 13; *Forced or Blast Draught*, 15 to 16.

Heating Surface per IHP.—*Natural Draught*, 2.44 to 2.61; *Steam Blast* 1.71 to 2.86; *Forced or Blast Draught*, 1.56 to 2.5.

Tube Surface per IHP *in Sq. Feet.—Natural Draught*, 2.03 to 2.18; *Steam Blast*, 2.02 to 2.08; *Forced or Blast Draught*, 1.3 to 2.8.

IHP *per Sq. Foot of Grate in these Trials.—Natural Draught*, 10.15 to 10.87; *Steam Blast*, 12.76 to 13.1; *Forced or Blast Draught*, 10.6 to 16.9.

Root's Rotary Blower—Is constructed from .125 to 14 nominal HP, supplying from 150 to 10 800 cube feet of air per minute. Delivery pipe 2.5 to 19 ins. in diameter. Efficiency 65 to 80 per cent. of power.

For *Ventilation of Mines*—From 40 to 280 revolutions per minute, equal to discharge of 12 500 to 200 000 cube feet of air per minute. 15.5 to 189 HP.

Steam cylinder from 14 × 18 ins. to 28 × 48 ins.

For other details of Blowing Engines see page 898.

CENTRAL FORCES.

All bodies moving around a centre or fixed point have a tendency to fly off in a straight line: this is termed *Centrifugal Force;* it is opposed to a *Centripetal Force*, or that power which maintains a body in its curvilineal path.

Centrifugal Force of a body, moving with different velocities in same circle, is proportional to square of velocity. Thus, centrifugal force of a body making 10 revolutions in a minute is 4 times as great as centrifugal force of same body making 5 revolutions in a minute. Hence, in equal circles, the forces are inversely as squares of times of revolution.

If times are equal, velocities and forces are as radii of circle of revolution.

The squares of times are as cubes of distances of centrifugal force from axis of revolution.

Centrifugal forces of two unequal bodies, having same velocity, and at same distance from central body, are to one another as the respective quantities of matter in the two bodies.

Centrifugal forces of two bodies, which perform their revolutions in same time, the quantities of matter of which are inversely as their distances from centre, are equal to one another.

Centrifugal forces of two equal bodies, moving with equal velocities at different distances from centre, are inversely as their distances from centre.

Centrifugal forces of two unequal bodies, moving with equal vel[illegible] ifferent distances from centre, are to one another as their quantities of ma[illegible] ed by their respective distances from centre.

Centrifugal forces of two unequal bodies, having unequal velo[illegible] ent distances from their axes are in compound ratio of their q[illegible] squares of their velocities, and their distances from centre.

Centrifugal force is to weight of body, as double height due to [illegible] of rotation.

A Radius Vector is a line drawn from centre of force to movi[illegible]

To Compute Centrifugal Force of any Body.

RULE 1.—Divide its velocity in feet per second by 4.01, also square of quotient by diameter of circle; this quotient is centrifugal force, assuming the weight of body as 1. Then this quotient, multiplied by weight of body, will give centrifugal force required.

EXAMPLE.—What is the centrifugal force of the rim of a fly-wheel having a diameter of 10 feet, and running with a velocity of 30 feet per second?

$$30 \div 4.01 = 7.48, \text{ and } 7.48^2 \div 10 = 5.59, \text{ or } \textit{times weight of rim.}$$

Or, $\frac{W\, n^2 \sqrt{R^2 + r^2}}{4100} = C$. *r representing radius of inner diameter of ring.*

NOTE.—Diameter of a fly-wheel should be measured from centres of gravity of rim.

When great accuracy is required, ascertain centre of gyration of body, and take twice distance of it from axis for diameter.

RULE 2.—Multiply square of number of revolutions in a minute by diameter of circle of centre of gyration in feet, and divide product by constant number 5217; quotient is centrifugal force when weight of body is 1. Then, as in previous Rule, this quotient, multiplied by weight of body, is centrifugal force required.

Or, $\frac{n^2 d}{5217} \times W$. *n representing number of revolutions per minute, d diameter of circle of gyration in feet, and W weight of revolving body in lbs.*

EXAMPLE.—What is centrifugal force of a grindstone weighing 1200 lbs., 42 ins. in diameter, and turning with a velocity of 400 revolutions in a minute?

Centre of gyration = rad. $(42 \div 2) \times .7071 = 14.85$ *ins.*, which $\div 12$ and $\times 2 =$ 2.475 *feet = diameter of circle of gyration.* Then $\frac{400^2 \times 2.475}{5217} \times 1200 = 91080$ lbs.

Formulas to Determine Various Elements.

$$C^* = \frac{W\, v^2}{32.166\, R}; = \frac{W\, R\, n^2}{2930}; = W\, R\, v'\, 1.225; \quad W = \frac{C\, 32.166\, R}{v^2};$$

$$R = \frac{2930\, C}{W\, n^2}; = \frac{W\, v^2}{32.166\, C}; \quad n = \sqrt{\frac{2930\, C}{W\, R}}; \quad v = \sqrt{\frac{C\, R\, 32.166}{W}}; = 6.28\, v' R$$

C representing centrifugal force, W mass or weight of revolving body, both in lbs., R radius of circle of revolving body in feet, n number of revolutions per minute, and v and v' linear or circumferential and angular velocities of body in feet per second.

ILLUSTRATION.—What is centrifugal force of a sphere weighing 30 lbs., revolving around a centre at a distance of 5 feet, at 30 revolutions per second?

$$v = \frac{5 \times 2 \times 3.1416 \times 30}{60} = 15.71 \textit{ feet.} \quad \text{Then } C\, \frac{30 \times 15.71^2}{32.166 \times 5} = 46.04 \textit{ lbs.}$$

Centrifugal forces of two bodies are as radii of circles of revolution directly, and as squares of times inversely.

ILLUSTRATION.—If a fly-wheel, 12 feet in diameter and 3 tons in weight, revolves in 8 seconds, and another of like weight revolves in 6, what should be the diameter of the second when their centrifugal forces are equal?

Then $3 : 3 :: \frac{12}{8^2} : \frac{x}{6^2}$; or $x = \frac{12 \times 6^2}{8^2} = 6.75$ *feet*, x = *unknown element.*

...ifugal forces of two bodies, when weights are unequal, are directly as squares...

...RATION.—What should be the ratio of the weights of the wheels in the ... case, their forces being equal?

$3 : x :: 6^2 : 8^2$, or $x = \frac{3 \times 8^2}{6^2} = \frac{3 \times 64}{36} = 5.333$ *tons.*

...orth gives $.00034\, W\, R\, n^2 = C$.

* This is termed the Vis Viva, or living force.

FLY-WHEEL.

LY-WHEEL by its inertia becomes a reservoir as well as a regulator :e, and to be effective should have high velocity, and its diameter l be from 3 to 4 times that of stroke of driving engine.

ifficient of fluctuation of energy in a machine ranges from .015 5.

ight of a fly-wheel in engines that are subjected to irregular mo- s in a cotton-press, rolling-mill, etc., must be greater than in others so sudden a check is not experienced, and its diameter should from 3.5 to 5 times length of the crank.

ngle acting engine requires a weight of wheel about 2.5 times greater hat for a double acting, and 5 times for double engines of double action.

To Compute Weight of Rim of a Fly-wheel.

.E.—Multiply mean effective pressure upon piston in lbs. by its stroke :, and divide product by product of square of number of revolutions, ter of wheel, and .000 23.

:.—If a light wheel is required, multiply by .0003; and if a heavy one, by

IPLE 1.—A non-condensing engine (double acting), having a diameter of cyl- of 14 ins., and a stroke of piston of 4 feet, working full stroke, at a pressure s. mercurial gauge, and making 40 revolutions per minute, develops about what should be the weight of its fly-wheel, when adapted to ordinary work?

of cylinder 154 *sq. ins. Mean pressure assumed* 50 *lbs. per sq. inch. Diam- wheel* 4 *feet stroke* $\times$ 3.5 = 14 *feet.*

$$50 \times 154 \times 4 = 30\,800, \text{ which } \div \overline{40^2 \times 14 \times .000\,23} = 5978 \textit{ lbs.}$$

f a fly-wheel, 16 feet in diameter and 4 tons in weight, is sufficient to regulate ine (double acting) when it revolves in 4 seconds, what should be the weight ieel, 12 feet in diameter, revolving in 2 seconds, so that it may have like cen- l force?

:.—The centrifugal forces of two bodies are as the radii of the circles of revo- lirectly, and as squares of times inversely.

$$\frac{4 \times 16}{4^2} = \frac{x \times 12}{2^2}. \quad \text{Or, } x = \frac{4 \times 16 \times 2^2}{12 \times 4^2} = \frac{4 \times 16 \times 4}{12 \times 16} = 1.333 \textit{ tons.}$$

me elements of example 1.

$$5978 \times .1 \div 13.25 = 45.12 \textit{ square ins.}$$

To Compute Dimensions of Rim.

E.—Multiply weight of wheel in lbs. by .1, and divide product by liameter of rim in feet; quotient will give sectional area of rim in inches of cast iron.

$\frac{S}{D} = W$, and $\frac{W}{10\,D} = A$. P *representing pressure on piston and* W *weight of* 1 *lbs.*, S *stroke of piston and* D *mean diameter of wheel, both in feet, and* A *section of rim in sq. ins.*

$\frac{16\,n\,P\,S\,C}{60\,D} = W$. C *representing coefficient varying from* 3 *to* 4 *or* [illegible] *reasing to* 6 *when great regularity of speed is required, and n number of revo- per minute.*

—Maximum safe velocity for cast iron is assume

ngines at high expansion of steam, or with irregu ltiply W by 1.5, or put W 100 lbs. for each IHP.

n or like mills, the velocity of periphery of fly-wh es

GOVERNORS.

A GOVERNOR OR CONICAL PENDULUM in its operation depends upon principles of Central Forces.

When in a *Ball Governor* the balls diverge, the ring on vertical sh[illegible] raises, and in proportion to the increase of velocity of the balls squ[illegible] or the square roots of distances of ring from fixed point of arms, c[illegible] responding to two velocities, will be as these velocities.

Thus, if a governor makes 6 revolutions in a second when ring is [illegible] ins. from fixed point or top, the distance of ring will be 5.76 ins. wh[illegible] speed is increased to 10 revolutions in same time.

For 10 : 6 :: $\sqrt{16}$: 2.4, which, squared = 5.76 ins., *distance of ri[illegible] from top.* Or, 6^2 : 10^2 :: 5.76 : 16 ins.

A governor performs in one minute half as many revolutions as [illegible] pendulum vibrates, the length of which is perpendicular distance [illegible] tween plane in which the balls move and the fixed point or centre [illegible] suspension.

To Compute Number of Revolutions of a Ball Govern[illegible] per Minute to maintain Balls at any given Height

[illegible] $\div \sqrt{H}$ = revolutions. *H representing vertical height between plane of b[illegible] and points of their suspension in ins.*

ILLUSTRATION.—If the rise of the balls of a centrifugal governor is [illegible] ins., w[illegible] are the number of revolutions per minute?

188 $\div \sqrt{}$[illegible] = [illegible] revolutions.

To Compute Vertical Height between Plane of Ba[illegible] and their Points of Suspension.

188 $\div n^2$ = vertical height in ins. *n representing number of revolutions per mi[illegible]*

ILLUSTRATION.—If number of revolutions of a centrifugal governor is 100, w[illegible] [illegible]

$$\overline{188 \div 100}^{\,2} = 1.88^2 = 3.53 \text{ ins.}$$

To Compute Angle of Arms or Plane of Balls w[illegible] Centre Shaft.

[illegible] = [illegible] *[illegible] representing distance of balls from plane of centre shaft, c[illegible] distance between balls and point of suspension measured in plane of shaft.*

ILLUSTRATION.—Distance of balls from plane of centre shaft is 10 inches, the distance from point of suspension is 25; what is the angle?

$10 \div 25 = .4$, and *sin.* $.4 = 23° 35'$.

When Number of Revolutions are given. $\dfrac{54.16 \div n^2}{l} = \cos \angle$.

ILLUSTRATION.—Revolutions of a governor per minute are 50, and length o[illegible] arms 2 feet, what is their angle with plane of shaft?

$$\frac{(54.16 \div 50)^2}{2} = \frac{1.173}{2} = .5865 = \cos.\ 54° 6'.$$

PENDULUMS.

Pendulums are *Simple* or *Compound*, the former being a mat[illegible] [illegible] single weight suspended from a fixed point, about whic[illegible] [illegible] [illegible]s, by a connection void of weight; and the la[illegible] [illegible]er of bodies suspended by a rod or connec[illegible] have as many centres of oscillation as the[illegible] [illegible]nsion to it, and when any one of these cen[illegible] [illegible]s are readily ascertained.

$s\, o \times s\, g =$ a *constant product*, and ...
ting points of suspension, gravity, oscillation ...

ny body, as a cone, a cylinder, or of any form ... ended as to be capable of vibrating, is a ... of its centre of oscillation from any assumed ... red as the length of an equivalent simple pendulum.

Amplitude of a simple pendulum is the distance ... rom its lowest position to its farthest on either side.

lete Period of a pendulum in motion is the time ... rations.

ibrations of same pendulum, whether great or small ... arly in same time.

ber of Oscillations of two different pendulums ... lace are in inverse ratio of square roots of their lengths.

th of a Pendulum vibrating seconds is in a constant ...

of Vibration is half of a complete period, and it is ... root of length of pendulum. Consequently, length ... t vibrations are—

Latitude of Washington.

0958 ins. for one second.	4.344 for third of a ...
.774 ins. for half a second.	2.4435 for quarter of a ...

ths of Pendulums vibrating Seconds ... the Sea in several Places.

	Ins.		Ins.		
....	39.0152	New York	39.1017	Paris	
gton......	39.0958	Lat. 45°	39.127	London	

ompute Length of a Simple Pendulum for a ... Latitude.

$39.127 - .099\,82 \cos. 2\,L = l.$ L *representing latitude.*

TRATION.—Required the length of a simple pendulum vibrating ... tude of 50° 31′.

$0° 31' \cos. 2\,L = 2 \times 50° 31' = \cos. 180° - \overline{50° 31' \times 2} = \cos.$ ...

$7 + \overline{.191\,38 \times .099\,82}$ (*two — or negative = an affirmative or* +) ...

ompute Length of a Simple Pendulum for a ... Number of Vibrations.

$= l.$ L *representing length for latitude, t time in seconds, and l length of ... in ins.*

TRATION.—Required vibrations of a pendulum in a minute at New York ... t should be its length?

$17 \times 1^2 = 39.1017.$ Or, $\frac{L}{n^2} = l.$ *n representing number of vibrations per* ...

ompute Number of Vibrations of a Simple Pendu- lum in a given Time.

$\frac{\sqrt{L't}}{\sqrt{l}} = n,$ $\frac{t}{n}$ *representing time of one vibration in seconds.*

ompute Centre of Gravity of a Compound Pendu- n of Two Weights connected in a Right Line.

When Weights are both on one Side of Point of

$\frac{\ \ w}{\ } = o =$ *distance of centre of gravity from point of*

When Weights are on Opposite Sides of Point of Suspension.

$\frac{l\,W - l'\,w}{W + w} = o$ = *distance of centre of gravity of greater weight from point of s pension.*

NOTE.—To obtain strictly isochronous vibrations, the circular arc must be s stituted for the cycloid curve, which possesses the property of having an incli tion, the sine of which is simply proportional to distance measured on the cu from its lowest point.

For construction of a Cycloidal pendulum, see Deschaniel's *Physics*, Part I, 71–2.

To Compute Length of a Simple Pendulum, Vibrati of which will be same in Number as Inches in Length.

$$\sqrt[3]{(\sqrt{L} \times 60)^2} = l \textit{ in inches.}$$

ILLUSTRATION.—What will be length of a pendulum in New York, vibratio which will be same number as the ins. in its length?

$$\sqrt[3]{(\sqrt{39.1017} \times 60)^2} = 7.211^2 = 52 \textit{ ins.}$$

To Compute Time of Vibration of a Simple Pendul Length being given.

$$\sqrt{l \div L} = t \textit{ in seconds.}$$

ILLUSTRATION.—Length of a pendulum is 156.4 ins.: what is the time of its v tion in New York?

$$\sqrt{\frac{156.4}{39.1017}} = 2 \textit{ seconds.}$$

Or, $\sqrt{\frac{L}{g}} \times 3.1416 = t$. *l representing length of a pendulum vibrating secon ins., g measure of force of gravity, and t time of one oscillation.*

ILLUSTRATION.—Length of a simple pendulum vibrating seconds, and measu force of gravity at Washington, are 39.0958 ins., and 32.155 feet.

$$3.1416\sqrt{\frac{39.0958}{32.155 \times 12}} = 3.1416 \times \sqrt{1.013} = 3.1416 \times .3183 = 1 \textit{ second.}$$

To Compute Number of Vibrations of a Simple P dulum in a given Time.

$$\sqrt{\frac{L}{l}} \times t = n. \quad n \textit{ representing number of vibrations.}$$

ILLUSTRATION.—The length of a pendulum in New York is 156.4 ins., and tir its vibration is 2 seconds; what are number of its vibrations?

$\sqrt{\frac{39.1017}{156.4}} \times 2 = \sqrt{\frac{6.253}{12.506}} \times 2 = .5 \times 2 = 1$ *vibration.* Hence, $1 \times \frac{60}{2} =$: *brations per minute.*

To Compute Measure of Gravity, Length of Pendul and Number of its Vibrations being given.

$$\frac{.82246\, l\, n^2}{t^2} = g. \quad g \textit{ representing measure of gravity in feet.}$$

To Compute Number of Revolutions of a Conical P dulum per Minute.

$\sqrt{\frac{2933}{}}$ ... *presenting* distance between point of suspension and pl

revol

r

th

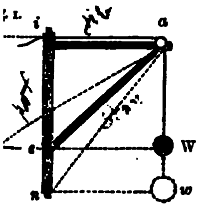
volutions per minute are constant for any given h is directly as square root of height.

CRANES.

Usual form of a Crane is that of a right-angled triangle, the sides ing **post or jib, and stay or strut,** which is hypothenuse of triangle.

When jib and post are equal in length, and stay is diagonal of a square, is form is theoretically strongest, as the whole stress or weight is borne by y, **tending to compress it in** direction of its length; stress upon it, com- red to weight supported, being as diagonal to side of square, or as 1.4142 1. **Consequently,** if weight borne by crane is 1000 lbs., thrust or com- ssion upon stay will be 1414.2 lbs., or as *a e* to *e* W, Fig. 1.

hen Post is Supported at both Head and Foot, as Fig. 1.



Weight W is sustained by a rope or chain, and tension is equal upon both parts of it; that is, on two sides of square, *i a* and *e* W. Consequently jib, *i a*, has no stress upon it, and serves merely to retain stay, *a e*.

If foot of stay is set at *n*, thrust upon it, as compared with weight, will be as *a n* to *a w*; and if chain or rope from *i* to *a* is removed, and weight is suspended from *a*, tension on jib will be as *i a* to *a* W.

If foot of stay is raised to *o*, thrust, as compared with weight, will be as e *a o* is to *a* W, and tension on jib will be as line *a r*.

By dividing line representing weight, as *a* W or *a w*, into equal parts, to present tons or pounds, and using it as a scale, stress upon any other part y be measured upon described parallelogram.

Thus, as length of *a* W, compared to *a e*, is as 1 to 1.4142: if *a* W is di- led into 10 parts representing tons, *a e* would measure 14.142 parts or tons.

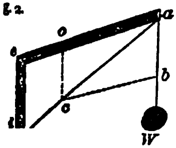
When Post is Supported at Foot only.

If post is wholly unsupported at head, and its foot is secured up to line V, then W, acting with leverage, *e* W, will tend to rupture post at *e*, with me effect as if twice that weight was laid upon middle of a beam equal to ice length of *e* W, *e* being at middle of beam, which is assumed to be sup- rted at both ends, and of like dimensions to those of post.

Or, force exerted to rupture post will be represented by stress, W, multi- ied by 4 times length of lever, *e* W, divided by depth of post in line of ess, squared, and multiplied by breadth of it and *Value** of its material.

Post of such a crane is in condition of half a beam supported at one end, ight suspended from other; consequently, it must be estimated as a beam twice the length supported at both ends, stress applied in middle.

o Compute Stress on Jib, and on Stay or Strut.-Fig. 2.



On diagram of crane, Fig. 2, mark off on line of chain, *a* W, a distance, *a b*, representing weight on chain; from point *b* draw a line, *b c*, parallel to jib, *a e*, and where this intersects stay or strut, draw a vertical line, *c o*, extending to jib, and distances from *a* to points *b c* and *o c*, measured upon a scale of equal parts, will represent proportiona'

Illustration.—In figure, weight being 1 on stay or strut compressing, *a c*, will be on jib or tension-rods, *a o*, 26 tons.

* *For Value of Materials, see page 779.*

To Compute Dimensions of Post of a Crane.

When Post is Supported at Feet only. RULE.—Multiply weight or stress to be borne in lbs. by length of jib in feet measured upon a horizontal plane; divide product by *Value* of material to be used, and product, divided by breadth in ins., will give square of depth, also in ins.

EXAMPLE.—Stress upon a crane is to be 22 400 lbs., and distance of it from centre of post 20 feet; what should be dimension of post if of American white oak?

Value of American white oak 50. Assumed breadth 12 ins.

$$\frac{22\,400 \times 20}{50} = 8960, \text{ and } \frac{8960}{12} = 746.67. \text{ Then } \sqrt{746.67} = 27.32 \textit{ ins.}$$

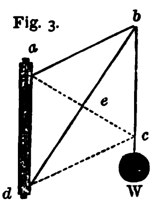
When Post is Supported at both Ends. RULE.—Multiply weight or stress to be borne in lbs. by twice length of jib in feet measured upon a horizontal plane; divide product by *Value* of material to be used, and product, divided by four times breadth in ins., will give square of depth, also in ins.

EXAMPLE.—Take same elements as in preceding case. Assumed breadth 10 ins.

$$\text{Then } \frac{22\,400 \times 20 \times 2}{50} = 17\,920, \quad \frac{17\,920}{4 \times 10} = 448, \text{ and } \sqrt{448} = 21.166 \textit{ ins.}$$

In Fig. 3, angle $a\,b\,e$ and $e\,b\,c$ being equal, chain or rope is represented by $a\,b\,c$, and weight by W; stress upon stay $b\,d$, as compared with weight, is as $b\,d$ to $a\,b$ or $b\,c$.

Fig. 3.



In practice, however, it is not prudent to consider chain as supporting stay; but it is proper to disregard chain or rope as forming part of system, and crane should be designed to support load independent of it. It is also proper that angles on each side of diagonal stay, in this case, should not be equal. If side $a\,b$ is formed of tension-rods of wrought iron, point a should be depressed, so as to lengthen that side, and decrease angle $a\,b\,e$; but if it is of timber, point a should be raised, and angle $a\,b\,e$ increased.

Fig. 4.

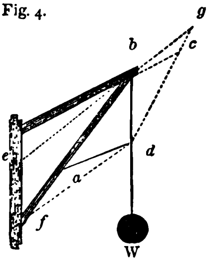
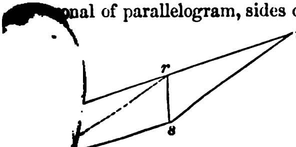


Fig. 4 shows a form of crane very generally used; angles are same as in Fig. 3, and weight suspended from it, being attached to point d, is represented by line $b\,d$. The tension, which is equal to weight, is shown by length of line $b\,c$, and thrust by length of line $b\,a$, measured by a scale of equal parts, into which line $b\,d$, representing weight, is supposed to be divided.

But if $b\,e$ be direction of jib, then $b\,g$ will show tension, and $b\,f$ the thrust ($d\,f$ being taken parallel to $b\,e$), both of them being now greater than before; line $b\,d$ representing weight, and being same in both cases.

To Ascertain Stress on Jib, on Strut of a Crane.—Fig. 5.

Through a draw $a\,s$, parallel to jib or tension-rod $o\,r$, and also $s\,u$ parallel to strut $a\,r$; then $r\,s$ is a [diag]onal of parallelogram, sides of which are equal to $r\,a$ and $r\,u$.



If then $r\,s$ represents a stress of 20 lbs., the two forces into which it is decomposed are shown by $r\,u$ and $r\,a$; $o\,r$ is equal to $r\,u$, as each of them is equal to $a\,s$, and $r\,s$ is equal to $o\,a$. Hence, as represented by $a\,o$, stress on jib will be represented by $o\,r$, and that on strut by $r\,a$.

Assuming then $o\,r$ 3 feet, $a\,r$ 3.5, and ... on jib will be 60 lbs., and on strut 70.

Thus, in all cases, stress on jib or tension-rod and on strut can be determined by relative proportions of sides of triangle formed.

To Compute Stress upon Strut of a Crane.

RULE.—Multiply length of strut in feet by weight to be borne in lbs.; divide product by height of jib from point of bearing of strut in feet, and quotient will give stress or thrust in lbs.

EXAMPLE.—Length of strut of a crane is 28.284 feet, height of post is 26.457 feet, and weight to be borne is 22 400 lbs.; what is stress?

$$\frac{28.284 \times 22\,400}{26.457} = \frac{633\,561.6}{26.457} = 23\,947 \; lbs.$$

Chains and Ropes.

Chains for Cranes should be made of short oval links, and should not exceed 1 inch in diameter.

Short-linked Crane Chains and Ropes showing Dimensions and Weight of each, and Proof of Chain in Tons.

Diam. of Chains.	Weight per Fathom.	Proof Strain.	Circumf. of Rope.	Weight of Rope per Fath.	Diam. of Chains.	Weight per Fathom.	Proof Strain.	Circumf. of Rope.	Weight of Rope per Fath.
Ins.	Lbs.	Tons.	Ins.	Lbs.	Ins.	Lbs.	Tons.	Ins.	Lbs.
.3125	6	.75	2.5	1.5	.6875	28	6.5	7	10.5
.375	8.5	1.5	3.25	2.5	.75	32	7.75	7.5	12
.4375	11	2.5	4	3.75	.8125	36	9.25	8.25	15
.5	14	3.5	4.75	5	.875	44	10.75	9	17.5
.5625	18	4.5	5.5	7	.9375	50	12.5	9.5	19.5
.625	24	5.25	6.25	8.7	1	56	14	10	22

Ropes of circumferences given are considered to be of equal strength with the chains, which, being short-linked, are made without studs.

A crane chain will stretch, under a proof of 15 tons, half an inch per fathom.

Machinery of Cranes.

To attain greater effect of application of power to a crane, the wheel-work must be properly designed and executed.

If manual labor is employed, it should be exerted at a speed of 220 feet per minute.

Proportions.—Capacity of Crane, 5 tons.

Radius of winch or handle 15 to 18 ins. Height of axle from floor 36 to 39.

1st pinion, 11 teeth, 1.25 ins. pitch. | 2d pinion, 12 teeth, 1.5 ins. pitch.
1st wheel, 89 " 1.25 " " | 2d wheel, 96 " " " "

$$\frac{\text{Barrel } 8 \; ins. \times 11 \; teeth \times 12 \; teeth \times 11\,200 \; lbs. = 30\,800}{\text{Winch } 17 \; ins. \times 89 \; teeth \times 96 \; teeth \times 4 \text{ men} = 1513} = 20.35 \; lbs. =$$ statical resistance to each of the 4 men at winches.

An experiment upon capacity of a crane, geared 1 to 105, developed that a strong man for a period of 2.5 minutes exerted a power of 27 562 foot-pounds per minute, which, when friction of crane is considered, is fr[illegible] the power of a horse for one minute.

In practice an ordinary man can develop a power of 15 lbs. [illegible] *handle moved at a velocity of* 220 feet per minute, which is e[illegible] *foot-pounds.*

For Treatise on Cranes, see Weales' Series, No. 33.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

These particulars are embodied in following summary of condition of ments of 100 lbs. of average coal, after having been decomposed, and prior entering into combustion—

100 *Lbs. of Average Coal in a Furnace.*

Composition	Lbs.		Lbs.	Decomposition.
bon Fixed	60	forming	60	fixed carbon.
bon Volatilized	20		24	hydrocarbons and free hydrogen.
drogen	5		1.25	sulphur.
phur	1.25		85.25	
gen	8		9	water or steam.
rogen	1.2		1.2	nitrogen.
, etc.	4.55		4.55	ash, etc.
	100		100	

wing a total useful combustible of 85.25 per cent., of which 25.25 per t. is volatilized. While the decomposition proceeds, combustion proceeds, d the 25.25 per cent. of volatilized portions, and the 60 per cent. of fixed bon, successively, are burned.

It may be added that the sulphur and a portion of the nitrogen are disgaged in combination with hydrogen, as sulphuretted hydrogen and amnia. But these compounds are small in quantity, and, for the sake of aplicity, they have not been indicated in the synopsis.

Volume of Air chemically consumed in complete Combustion of Coal.

Assume 100 lbs. of average coal. Then, by following

$80+3\left(5-\frac{8}{8}\right)+\overline{.4\times 1.25}\times 152=14\,060$ *cube feet of air at 62° for 100 lbs. coal.*

For volatilized portion, Hydrogen (H),	4	lbs. × 457 =	1 828	cube feet.
Carbon (C),	20	" × 152 =	3 040	" "
Sulphur (S),	1.25	" × 57 =	71	" "
			4 939	" "
For fixed portion, Carbon,	60	lbs. × 152 =	9 120	" "
Total useful combustible,	85.25	"	14 059	" " *for com-*

ete combustion of 100 *lbs. coal of average composition at* 62°.

o Compute Volume of Air at 62°, under One Atmosphere, chemically consumed in Complete Combustion of 1 Lb. of a given Fuel.

Rule.—Express constituent carbon, hydrogen, oxygen, and sulphur, as rcentages of whole weight of fuel; divide oxygen by 8, deduct quotient om hydrogen, and multiply remainder by 3; multiply sulphur by .4; add oducts to the carbon, and multiply sum by 1.52. Final product is volume air in cube feet.

To compute weight of air chemically consumed.—Divide volume thus found 13.14; quotient is weight of air in lbs.

$$\text{Or, } 1.52\left(C+3\left(H-\frac{O}{8}\right)+.4\,S\right)=Air. \quad O\ \textit{Oxygen.}$$

Note.—In ordinary or approximate computations, sulphur may be

Example.—Assume 1 lb. Newcastle coal. $C=82.24$, $H=5.42$, $=1.35$.

$\frac{6.44}{8}=.805$, $5.42-.805=4.615\times 3=13.845$, $1.35\times .4=.54$, 13.845 96.625, and $96.625\times 1.52=146.87$ *cube feet.*

Then $146.87\div 13.14=11.18$ lbs.

Labor.

For labor of a man, see Animal Power, pp. 433–34.

By Wheel-barrow.—A barrow-load may be assumed at 175 lbs. = 2 cube feet of space.

Blasting. —When labor is $1 per day, hard rock in ordinary position may be blasted and loaded for 45 cents per cube yard.

The cost, however, in consequence of condition, position, etc., may vary from ... cents to $1

See Blasting page 443.

17 cube yards of hard rock may be carted per day over a lead of 100 feet, at a cost of 7.29 cents per yard.

The preceding elements are essentially deduced from notes furnished by Elwood Morris, C.E.. and the valuable treatise of John C. Trautwine, C.E., Phila., 1872.

Stone.

Hauling Stone.—A cart drawn by horses over an ordinary road will travel 1.15 miles per hour of trip = 2.3 miles per hour.

A four-horse team will haul from 25 to 36 cube feet of stone at each load.

Time expended in loading, unloading, etc., including delays, averages 35 minutes per trip. Cost of loading and unloading a cart, using a horse-crane at the quarry, and unloading by hand, when labor is $1 25 per day, and a horse 75 cents, is 25 cents per perch = 24.75 cube feet = 1 cent per cube foot.

Work done by an animal is greatest when velocity with which he moves is .125 of greatest with which he can move when not impeded, and force then exerted .45 of utmost force the animal can exert at a dead pull.

Earthwork. (*Molesworth.*)

Proportion of Getters, Fillers, and Wheelers in different soils, Wheelers being calculated at 50 yards run.

	Gett's.	Fill's.	Wheel's.		Gett's.	Fill's.	Wheel's.
In loose earth, sand, etc.	1	1	1	In Hard clay.....	1	1.25	1.25
" Compact...........	1	2	2	" Compact gravel	1	1	1
" Marl...............	1	2	2	" Rock, from....	3	1	1

Average Weight of Earths, Rocks, etc.

Per cube yard.

	Lbs.		Lbs.		Lbs.		Lbs.
Sand	3360	Marl.........	2912	Sandstone ...	4368	Granite	4700
Gravel.......	3360	Clay.........	3472	Shale.........	4480	Trap.........	4700
Mud.........	2800	Chalk	4032	Quartz.......	4492	Slate.........	4710

Bulk of Rock, Earthwork, etc., Original Excavation assumed at 1.

When in Embankment.

Rock, large.................	1.5 1.6 1.7	Sand and gravel..................	1.07
Medium...................	1.25 to 1.7	Clay and earth after subsidence...	1.08
Metal	1.2 to 1.8	" " before "	... 1.2

In small stones, per cent. of interstices to total volume is 44 to 48, which is an increase in volume of solid rock to fragments of 79 and 92 per cent.

The relative proportions of Earth in Bank and Embankments, as given by different authorities, are so varied and so opposite that it is evident the difference is accidental, depending, primarily, upon the season, location, and character or condition ... earth and then upon the height of the embankment, the manner and dur... ...ing it.

...ris, ante p. 466, makes the embankment less, and Molesworth, ...ter.

STRATION.—What is temperature of combustion of coal of average composi-

:ous products as per preceding table 11.94, which $\times$ .246 specific heat $=$ 2.935 *of heat at* 1°.

ce, 14 133 units of combustion (from table, page 461) $\div$ 2.935 $=$ 4812° *temper. of combustion of average coal.*

irplus air is mixed with products of combustion equal to volume of air chem. combined, total weight of gases for one lb. of this coal is increased to 22.64. llowing table, having a mean specific heat of .242.

n 22.64 $\times$ .242 $=$ 5.478 *units for* 1°.

ice, 14 133 total heat of combustion $\div$ 5.478 $=$ 2580° temperature of combus- or a little more than half that of undiluted products.

king averages, it is seen that the evaporative efficiency of coal varies ly with volume of constituent carbon, and inversely with volume of ituent oxygen; and that it varies, not so much because there is more or arbon, as, chiefly, because there is less or more oxygen. The per-cent- of constituent hydrogen, nitrogen, sulphur, and ash, taking averages, early constant, though there are individual exceptions, and their united , as a whole, appears to be nearly constant also.

Heat of Combustion.

number of times in combustion of a substance, its equivalent weight of water l be raised 1°, *by heat evolved in combustion of substance.*

iol	12 930	Ether	16 246	Olefiant gas	21 340
coal	14 545	Olive oil	17 750	Hydrogen	62 030

Combustion of Fuel.

onstituents of coal are *Carbon*, *Hydrogen*, *Azote*, and *Oxygen*.

olatile products of combustion of coal are hydrogen and carbon, the ms of which (relating to combustion in a furnace) are *Carburetted ogen* and *Bi-carburetted hydrogen* or *Olefiant gas*, which, upon com- ng with atmospheric air, becomes *Carbonic acid* or *Carbonic oxide*, *m*, and uncombined *Nitrogen*.

arbonic oxide is result of imperfect combustion, and Carbonic acid of perfect combustion.

erfect combustion of carbon evolves heat as 15 to 4.55 compared imperfect combustion of it, as when carbonic oxide is produced.

lb. carbon combines with 2.66 lbs. of oxygen, and produces 3.66 lbs. arbonic acid.

oke is the combustible and incombustible products evolved in combustion of which pass off by flues of a furnace, and it is composed of such portions of ogen and carbon of the fuel gas as have not been supplied or combined with en, and consequently have not been converted either into steam or carbonic the hydrogen so passing away is invisible, but the carbon, upon being sepa- from the hydrogen, loses its gaseous character, and returns to its elementary of a black pulverulent body, and as such it becomes visible.

uminous portion of coal is converted into gaseous state alone, carbonaceous on only into solid state. It is partly combustible and partly incombustible.

effect combustion of 1 cube foot of coal gas, 2 cube feet of oxygen are required; ts 10 cube feet of atmospheric air are necessary to supply this volume of — cube foot of gas requires oxygen of 10 cube feet of air.

furnaces with a natural draught, volume of air required exc *the draught is produced* artificially.

insufficient supply of air causes imperfect combustion; an *a waste of heat.*

14. When fibres of materials cross each other, friction is less than whe[n] they run in the same direction.

15. Friction is greater between surfaces of the same character than be- tween those of different characters.

16. With hard substances, and within limits of abrasion, friction is as pressure, without regard to surfaces, time, or velocity.

17. The influence of duration of contact (friction of rest) varies with the nature of substances; thus, with hard bodies resting upon each other, the effect reaches a maximum very quickly; with soft bodies, very slowly; with wood upon wood, the limit is attained in a few minutes; and with metal on wood, the greatest effect is not attained for some days.

Coefficient of Friction of Journals.

Diameters from 2 to 4 ins. Speeds varied as 1 to 4. Pressure up to 2 tons.

(From data of M. Morin.)

Surfaces of Contact. Journals. / Bearings.	Lubrication.	Coefficient* pressure = 1. Ordinary Lubrication.
Cast iron on cast iron	Olive oil, or tallow	.07 to .08
	Unctuous and wet	.14
Cast iron on gun metal	Olive oil, or tallow	.07 to .08
	Unctuous and wet	.16
Cast iron on lignum-vitæ	Slightly unctuous	.18
	Oil, or lard	—
	Lard and plumbago	.14
Wrought iron on cast iron	Olive oil, or tallow	.07 to .08
Wrought iron on gun metal	Olive oil, or tallow	.07 to .08
	Unctuous and wet	.19
	Slightly unctuous	.25
Wrought iron on lignum-vitæ	Oil	.11
	Unctuous	.19
Gun metal on gun metal	Oil	.1
Lignum-vitæ on cast iron	Unctuous	.15

* Continuous lubrication reduces the coefficients fully one half.

Surfaces of Contact.	Disposition of Fibres and Lubrication.	Coefficient pressure = 1.
...ak	Parallel and soaped	.16
...on on oak	" " wet	.26
"	" " soaped	.21
...n oak	" " wet	.22
"	" " soaped	.19
... oak	" " wet	.29
...lt on oak (flat)	" " dry	.27
" on oak pull...	Perpendicular " "	.47

...r belts over ... .47 of pressure, and over turned cast-iron pulley[s] ...essure.

C... of Friction of Motion.

		Condition of Surfaces and Unguents.						
		Dry.	Water.	Olive-oil.	Lard.	Tallow.	Dry Soap.	Grease ...
...	On wood	.45	.33	—	—	—	—	—
	On iron.	—	—	.15	—	.19	—	—
...	Mean	.18	.31	.07	.09	.09	.2	.3
...ood	Raw	.54	.36	.16	—	.2	—	—
	Dry	.34	.31	.14	—	.14	—	—
...	Mean	.42	.24	.06	.07	.06	.2	
...		.36	.25	—	.07	.07	.15	

Relative Value of Unguents to Reduce Friction.

Unguents.	Wood upon Wood.	Wood upon Metals.	Metals upon Metals.	Unguents.	Wood upon Wood.	Wood upon Metals.	Metals upon Metals.
ry soap	.4	.32	.27	Olive oil	—	1	1
ard	.82	.85	.7	Tallow	1	.93	.8
ard and plumbago.	—	.67	.96	Water	.22	.24	.18

To Determine Coefficient of Friction of Bodies.

Place them upon a horizontal plane, attach a cord to them, and lead it in direction parallel to the plane over a pulley, and suspend from it a scale in which weights are to be placed until body moves.

Then weight that moves the body is numerator, and weight of body moved s denominator of a fraction, which represents coefficient required.

Illustration.—If, by a pressure of 320 lbs. friction amounts to 80 lbs., its coeffi-ient of friction in this case would be $80 \div 320 = .25$.

Hence, if coefficient of friction of a wagon over a gravel road was .25, and the load 400 lbs., the power required to draw it would be $8400 \times .25 = 2100$ *lbs.*

Coefficients of Axle Friction. (*M. Morin.*)

Substances.	Dry and a little Greasy.	Greasy and wet with Water.	Oil, Tallow, or Lard. In usual way.	Oil, Tallow, or Lard. Continuously.	Very soft and purified Carriage Grease.
Bell metal upon bell metal	....	....	.097	....	....
Cast iron upon bell metal	.194	.161	.075	.054	.065
Cast iron upon cast iron	....	.079	.075	.054	....
Cast iron upon lignum-vitæ	.185	....	.1	.092	.109
Wrought iron upon bell metal	.251	.189	.075	.054	.09
Wrought iron upon cast iron	....	....	.075	.054	....
Wrought iron upon lignum-vitæ	.188	....	.125	....	....

Friction of a journal of an axle which presses on one side only, as in a worn bearing, is less than when it presses at all points, the difference being about .005.

Friction of Axles.—With axles, friction of motion has alone been experimented upon. When weight upon axle and radius of its journal is given, *mechanical effect* of friction may be readily determined.

The mechanical effect absorbed by, or of friction, increases with pressure or weight upon journal of axle and number of revolutions.

Friction of an axle is greater the deeper it lies in its bearing.

If journal of an axle lies in a prismatic bearing, as in a triangle, etc., friction is greater, as there is more pressure on, and consequently greater friction in contact: in a triangular bearing it is about double that of a cylindrical bearing.

To Compute Mechanical Effect of Friction of an Axle.

$\frac{p\,n\,f\,W\,r}{30} = F.$ *n representing number of revolutions, and r* ... *in feet.*

Illustration.—*Weight of a* wheel, with its axle or shaft resti... *is 360 lbs.; diameter of journals 2 ins.*; and number of revolutio... *chanical effect of the friction,* the coefficient of it being .16?

$$\frac{3.1416 \times 30 \times .16 \times 360 \times \overline{1 \div 12}}{30} = \frac{452.4}{30} = 15.08$$

By application of friction-wheels (rollers) friction is much reduced, and mechanical effect then becomes, when weights of friction-wheels are disregarded,

$\frac{p\,n\,f\,W\,r}{30} \times \frac{r'}{a'\ cos.\ \overline{a \div 2}} = F$. *$r'$ representing radii of axles of friction-wheels, a' radii of friction-wheels, and a angle of lines of direction between axis of roller and axis of friction-wheels.*

When a single friction-wheel is used, $\frac{2\,p\,r\,n}{60} \times f\,W = F$, and $\frac{F}{r' \div a'} = F'$. *$F'$ representing mechanical effect.*

ILLUSTRATION.—A wheel and its shaft, making 5 revolutions per minute, weighs 30 000 lbs.; its diameter and that of its journals are 32 feet and 10 ins. The journals rest upon a friction-wheel, the radius of which is 5 times greater than its axle.

1. What is the power at circumference of wheel necessary to overcome friction? 2. What is mechanical effect of the friction? 3. What is reduction of friction by use of the friction-wheel?

1. $\frac{\overline{32 \div 2} \times 12}{10 \div 2} = 38.4$, *circum. of wheel* $= 38.4$ *times that of axle.*

Coefficient of friction assumed at .075. Hence $\frac{30\,000 \times .075}{38.4} = 58.59$ *lbs. = power at circum. to overcome friction at axle.* 2. $\frac{10 \times 3.1416}{12} = 2.618$ *feet = distance passed by friction.*

Consequently, $\frac{2.618 \times 5}{60} = .2181$ *feet = distance passed by friction in one second.*

Hence, $.2181 \times 2250\ (30\,000 \times .075) = 490.725$. 3. $1 \div 5 = .2 =$ *radius of friction-axle ÷ by radius of friction-wheel,* and $38.4 \times .2 = 7.68 =$ *friction referred to circum. of wheel, and* $\frac{490.725}{5} = 98.145 =$ *mechanical effect by application of friction-wheel = a reduction of four fifths.*

Friction of Pivots.

Friction on Pivots is independent of their velocity, increases in a greater degree than their pressures, and approximates very near to that of sliding and axle friction.

Friction on Conical Bearings is greater than with like elements on plane surfaces.

Figure of point of a pivot, as to its acuteness, affects friction: with great pressure the most advantageous angle for the figure ranges from 30° to 45°; with less pressure it may be reduced to 10° and 12°.

Relative Value of Angles of Pivots.

6°	1	15°	.66	45°	.39

Relative Values of different Materials for use as Pivots.

Agate	.83	Granite	1	Tempered steel	.44
Glass	.55	Rock crystal	.76		

…on and Rigidity of Cordage.

…monton and Coulomb, with an apparatus of Amonton's, … deductions:

…aused by stiffness of cords about the same or like … the suspended weight.

…aused by stiffness of cords increases not only in direct … ed weights, but also in direct proportion of diamete…

Consequently, that resistance to motion over the same or like pulleys, arising from stiffness of cords, is in direct compound proportion of suspended weight and diameter of cords.

3. That resistance to bending varied inversely as diameter of sheave or drum.

4. That complete resistance is represented by expression $\frac{S+CT}{d}$. S *representing constant for each rope and sheave, expressing stiffness of rope;* T *tension of rope which is being bent, expressed by* C T; C *constant for each rope and sheave; and d diameter of sheave, including diameter of rope.*

5. That stiffness of tarred ropes is sensibly greater than that of white ropes.

Extending results obtained by Coulomb, Morin furnishes following *formulas:*

For White Ropes: $12\,n \div d\,(.002\,15 + .001\,77\,n + .0012\,W) = R$. *For Tarred Ropes:* $12\,n \div d\,(.010\,54 + .0025\,n + .0014\,W) = R$. R *representing rigidity in lbs., n number of yarns, d diameter of sheave in ins. and rope combined, and* W *weight in lbs.*

Illustration.—What is value of stiffness or resistance of a dry white rope having a diameter of 60 yarns, which runs over a sheave 6 ins. in diameter in the groove, with an attached weight of 1000 lbs.?

Assume diameter for 60 yarns to be 7.2 *ins.* Then $\frac{12 \times 60}{7.2}(.002\,15 + .001\,77 \times 60 + .0012 \times 1000) = 100 \times 1.308\,35 = 130.835$ *lbs.*

Value of natural stiffness of ropes increases as the square of number of threads nearly, and value of stiffness proportional to tension is directly as number of threads, being a constant number. Hence, having the rigidity for any number of threads, the rigidity for a greater or lesser number is readily ascertained.

Wire Ropes.

Weisbach deduced from his experiments on wire ropes that their rigidity or diameters capable of supporting equal strains with hemp ropes is considerably less.

Wire ropes, newly tarred or greased, have about 40 per cent. less rigidity than untarred ropes.

Rolling Friction.

Rolling Friction increases with pressure, and is inversely as diameter of rolling body.

For rolling upon compressed wood, $f = .019$ to $.031$.

When a Body is moved upon Rollers and Power applied at the Base of the Body, $(f+f')\frac{W}{r} = F$. *f and f' representing coefficients of friction of two surfaces upon which rollers act.*

When Power is applied at Circumference of Roller, $f\,W \div r = F$.

When Power is applied at Axis of Roller, $f\,W \div \overline{r \div 2} = F$.

Bearings for Propeller Shaft. (*Mr. John Pe*

Bearings.	Pressure per Sq. Inch.	Time of Operation.	Bearings.
	Lbs.	Min.	
Babbit's metal on iron*	1600	8	Brass on iron†
Box on brass	4480	5	Brass on iron‡
Box on iron	448	30	Lignum-vitæ on brass
Brass on brass	448	30	Snake-wood on brass
Brass on iron	448	30	Lignum-vitæ on iron

* Rolled out. † Abraded. ‡ Set fast.

Result of Experiments upon Friction of Several Instruments. (*R. S. Ball.*)

INSTRUMENT.	Friction.	Velocity ratio.	Mechanical efficiency.	Useful effect.
	F L			Per Cent.
Pulley, single	2.21 +.5453	2	1.8	90
" 3 sheaves	2.36 +.238	6	4	64
" differential	3.87 +.151	16	6.1	36
Screw	.0 +.014	193	70	36
Inclined plane, angle 17° 2′	.09 +.55	3.4	1.72	51
Screw Jack	.66 +.007	414	116	28
Wheel and Axle	.204 +.043	31	22	70
" " Barrel	.5 +.169	5.95	5.55	93
" " Pinion	2.46 +.21	8	4.1	51
Crane	.0 +.056	23	18	78
"	.185 +.008	137	87	63

F *representing friction, and* L *load.*

ILLUSTRATION 1.—If it is required to ascertain power necessary to raise 200 lbs. 2 feet, by a single movable pulley, $200 \times .5453 + 2.21 = 111.27$ *lbs.*, which must be applied as power to raise 200 lbs. 2 feet. $111.27 \times 2 = 222.54$ *lbs.* Hence, for application of 222.54 lbs., 200 or 89.87 *per cent. are usefully or effectively employed.*

2.—If it is required to raise 100 lbs. by a three-sheave pulley, then $100 \times .238 + 2.36 = 26.16$ *lbs*, which must be applied as power to raise 100 lbs. 6 feet ($3 \times 2 = 6$). $26.16 \times 6 = 156.96$ *lbs.* Hence, for application of 156.96 lbs., 100 or 63.71 *per cent. are effectively employed.*

3.—The velocity ratio of a crane being 137, and its mechanical efficiency 87, a man applying 26 lbs. to it can raise $87 \times 26 = 2262$ *lbs.*

Application of preceding Results.

ILLUSTRATION.—If a vessel, including cradle, weighing 1000 tons, is to be drawn upon an inclined plane having a rise of 10 feet in 100 of its length, what will be the resistance to be overcome, the cradle being supported on wrought-iron axles in cast-iron rollers, running on cast-iron rails?

$\frac{1000 \times 10}{100} = 100$ *tons = power required to draw vessel independent of friction.*

Ratio of friction to pressure of wrought iron on cast, in an axle and its bearing, .075. Ratio of ditto of cast iron upon cast, say .005.

Hence $.075 + .005 = .08$ of 1000 tons = 80 *tons*, which, added to 100 tons before deducted, gives 180 *tons, or resistance to be overcome.*

Power or effect lost by friction in axles and their bearing may be expressed by formula

$\frac{W f d r}{230} = P.$ *f representing coefficient of friction, d diameter of axle in ins., and r number of revolutions per minute.*

ILLUSTRATION.—Pressure on piston of a steam-engine is 20000 lbs., number of revolutions 20, and diameter of driving shaft of wrought iron in a brass journal is 8 ins.; what is the effect of friction?

$$\frac{20000 \times .07 \times 8 \times 20}{230} = 973.91 \text{ lbs.}$$

Hence $P\,v \div 33000 =$ IP. *v representing circumference of shaft in feet × by revolutions per minute.*

The power or effect lost by friction in guides or slides may be expressed by following formula:

$\frac{W f s r}{60 \times \sqrt{(5\,l^2 - s^2)}} = P.$ s representing stroke of cross-head, and l length of connecting rod in feet.

Frictional Resistances.

Friction of Steam-engines.

ction of Condensing Engines in Lbs. per Sq. Inch of Piston.

ıeter ıer.	Oscillating and Trunk.	Beam and Geared.	Direct-acting and Vertical.	Diameter of Cylinder.	Oscillating and Trunk.	Beam and Geared.	Direct-acting and Vertical.
	5	6	7	50	2.5	2.7	3.3
	4	5	6	60	2.4	2.6	3
	3.5	4	5	70	2.3	2.5	2.7
	3	3.6	4.5	80	2	2.3	2.6
	3	3.5	4	100	1.6	2.2	2.5
	2.6	3	3.5	110	1.5	2	2.1

ːperiments upon different steam-engines have determined that friction, ı pressure on piston is about 12 lbs. per sq. inch, does not exceed 1.5 lbs., ›out one tenth of power exerted.

iction of double cylinder (50-inch diam.) direct-acting condensing pro-r engine is 1.25 lbs. per sq. inch of piston = 10.3 per cent. of total power loped; friction of load is .9 lbs. per sq. inch of piston = 7.5 per cent. of pressure; and friction of propeller is 1.3 lbs. per sq. inch of piston = per cent. of total power = 28.6 per cent.

·iction of double cylinder (70-inch diam.) inclined condensing water-ɜl engine with its load is 15 per cent. of total power developed.

general, when engines are in good order, their efficiency ranges from 80 ːent. for small engines to 93 per cent. for large.

›wer required to work air-pumps is 5 per cent., and to work feed-pumps r cent.

sults of Experiments upon Friction of Machinery.

(*Davison.*)

'eam-engine, vertical beam, one tenth its power; 190 feet horizontal, and feet vertical shafting, with 34 bearings, having an area of 3300 sq. ins., ı 11 pair of spur and bevel wheels; 7.65 IP.

ɜt of three-throw Pumps, 6 ins. in diam., delivering 5000 gallons per hour a elevation of 165 feet; 4.7 IP, or about 13 per cent.

wo pair iron Rollers and an elevator, grinding and raising 320 bushels t per hour; 8.5 IP.

le-mashing Machine, 800 bushels malt at a time; 5.68 IP.

rchimedes Screw (ninety-five feet), 15 ins. in diameter, and an elevator reying 320 bushels malt per hour to a height of 65 feet; 3.13 IP.

'riction Clutch.—Driven by a leather belt 14 ins. in width; face of clutch s. deep; broke a cast-iron shaft 6.5 ins. in diameter.

'lax Mill (*M. Cornut*, 1872).—Two condensing engines. cylinders, 12.9 × 44.3 ins. stroke, and 22 ins. × 59.8 ins. stroke. F [illegible] steam, bs. per sq. inch; revolutions, 25 per minute. Friction [illegible] ·in-20 per cent.

'ith vegetable *oil and hand* oiling a steam pressur[illegible] *was required, and with* mineral oil and continuous *ı only was required.*

continuous oiling, a saving of 44 per cent. was

Flax Mill.

Power required to Drive Engine, Shafting, and entire Machinery. (*M. Cornut.*)

Parts.	Total.	Indicated Horse-power. One Machine at work.	empty.	Effect of Machine.
Engines, shafting, and belts	30.41	—	—	—
4 cards	8.42	2.105	1.423	32
14 drawing frames (29 heads or 156 slivers)	7.19	.0934	.0794	15
4 combing machines	2.22	.555	.151	78
6 roving frames (330 spindles)	7.78	.02627*	2.434	7.3
20 spinning frames.				
Dry (1480 spindles)	47.5	.0321*	2.515	21.6
Wet (2080 ")	46.59	.0224*	1.613	19

Total 150.11 IP.

* Per 100 spindles.

Estimate of Horse's Power.—2080 spindles, wet, 34.4 per IP, long fibre.
640 " dry, 20.1 " " " "
840 " " 14.5 " " tow.
3560 " average, 23.7 " "

The IP per 100 spindles varies inversely as sq. root of their number.

Winding Engine (*G. H. Daglish*).

Shafts 738 *to* 1740 *feet in depth; cylinder* 65 × 84 *ins. stroke; pressure of steam* 19 *lbs. per sq. inch; revolutions* 12.5 *per minute; mean diameter of drum,* 26 *feet.* IP 313.4; effect 235 = 75 per cent.

Tools. (*Dr. Hartig*).

Single shearing, $.1 + \frac{n\,t^2}{26.7} =$ IP *to drive tool.* *n representing number of cuts per minute, t thickness of plate,* and $\frac{a\,F}{1\,980\,000} =$ IP *to shear.* *a representing area of surface cut or punched per hour in sq. ins., and* F (1166 + 1691 *t*) *a factor expressing work required to cut or shear a surface of* 1 *inch square.*

Illustration.—A shearing machine cutting 4648 sq. ins. of surface per hour, in plates .4 inch thick, required .68 IP to run and 4.3 to operate it, equal to 5 horses.

Iron Plate-bending. $\frac{85\,000\,b\,t^2\,l}{r} =$ P *for cold plates,* and $\frac{11\,300\,b\,t^2\,l}{r}$ = P *for red-hot plates.* *b, t, and l representing breadth, thickness, and length of plate, r radius of curvature, all in ins., and* P *net power of bending.*

Power for large rolls when running only .5 to .6 IP.

Ordinary Cutting Tools, in Metal.

Materials of a brittle nature, as cast iron, are reduced most economically in power consumed, by heavy cuts; while materials which yield tough curling shavings are more economically reduced by thinner cuttings. Following formulas apply to light cutting work:

Power required to plane cast iron is—

Planing Cast iron, W $\left(.0155 + \frac{1}{11\,000\,s}\right) =$ IP. W *representing weight of cast* [...]*ved per hour, in lbs.*, and *s average sectional area of shavings, in sq. ins.*

[...]ght iron, and Gun-metal, with cuts of an average character—

[...]2 W = IP | Wrought iron, .052 W = IP | Gun-metal, .0127 W = IP

[...]nd **Molding.**—Run without cutting. $\frac{N}{2000} =$ IP. N [...] *revolutions of all the shafts per minute.*

Molding. — Pine, $.0566 + \frac{.02268}{h}$, and Red Beech, $.08895 + \frac{.00731}{h} =$ IP. *h representing depth of wood cut down to form molding.*

Turning. — Steel, .047 W = IP; Wrought iron, .0327 W = IP; Cast iron, 314 W = IP.

For turning off metals, power required is less than for planing, and it is ascertained that greater power is required for small diameters than large.

Light Lathes, $.05 + .0005\,n =$ IP; 1 or 2 shafts, $.05 + .0012\,n =$ IP; 3 or 4 shafts, $5 + .05\,n =$ IP. *Heavy Lathes*, $.025 + .0031\,n$; $.025 + .053\,n$; $.025 + .18\,n$.
n representing number of revolutions of spindle per minute.

Drilling.—Power required to remove a given weight of metal is greater than . planing. Volume being taken in place of weight.

Holes from .4 to 2 ins. in diameter.

Cast iron, dry. $V\left(.0168 + \frac{.00067}{d}\right) =$ IP. Wrought iron, oil. $V\left(.0168 + \frac{.0269}{d}\right) =$ IP.

V representing volume removed in cube ins. per hour, and d diameter of hole.

Without gearing, $.0006\,n + .0005\,n'$; with gearing, $.0006\,n + .001\,n'$; radial drills without gearing, $.0006\,n + .004\,n'$; radial drills with gearing, $.04 + .0006\,n + .04\,n'$. *n representing number of revolutions per minute of gearing shaft, and n' drill.*

Slotting.—Stroke 8 ins. $.045 + \frac{n\,s}{4000} =$ IP. *n representing number of strokes per minute, and s stroke in ins.*

Wood-sawing, Circular.—A cube foot of soft wood and half a cube foot of hard, reduced to sawdust, requires 1 IP.

Hard wood, $\frac{A\,c}{6} =$ IP′. Soft wood, $\frac{A\,c}{12} =$ IP′. A *representing area in sq. feet and* IP′ *horse-power per sq foot, both cut per hour, and c width of cut in ins.*

From .4 to 4 ins. in diameter.—Pine. $V\left(.000125 + \frac{.00656}{d}\right) =$ IP.

Dry pine timber. $.00428 + .0065\,\frac{S\,c}{f} =$ IP′. S *representing stroke of saw in feet, and f feed per cut in ins.*

$\frac{n\,d}{32000} =$ IP *for horse-power to run only without cutting. d representing diameter of saw in ins., and n number of revolutions per minute.*

Net power required to cut with a circular saw is proportional to volume of material removed. For a saw cutting hot iron, at a circumferential speed of 7875 feet per minute, and making a cut .14 inch wide, power is expressed by formulas—

.702 A = IP, for red-hot iron. 1.013 A = IP, for red-hot steel.

A representing sectional area of surface cut through, in sq. feet.

Vertical Saw. $.00428 + .0065\,\frac{S\,c}{f} =$ IP *in dry pine timber per sq. foot per hour.* S *representing stroke of saw in feet, c width of cut in ins., and f feed of it in ins.*

Band Saw. $.0034 + \frac{.758\,c\,v}{10000\,f} =$ IP′ *in Pine.* $.00483 + \frac{.957\,c\,v}{10000\,f} =$ IP′ *in Oak.* $.0576 + \frac{1.127\,c\,v}{10000\,f} =$ IP′ *in Beech. v representing velocity of* ... *f rate of feed, feet per minute.*

Screw Cutting. Screws, $\frac{5\,l\,d^3}{64} =$ IP. Taps, $\frac{l}{\ldots}$
diameter in ins., and l length cut in feet per hour.

Machine of medium dimensions, .2 IP.

Coal.

Anthracite.

***Anthracite or Glance Coal, or Culm*—Is hard, compact, lustrous, and sometimes iridescent, most perfect being entirely free from bitumen; it ignites with difficulty, and breaks into fragments when heated.**

Evaporative power, in furnace of a steam-boiler and under pressure, is from 7.5 to 9.5 lbs. of fresh water per lb. of coal.

Coal from one pit will sometimes vary 6 per cent. in evaporative value.

Elements of Various American Coals.

	Specific Gravity.	Fixed Carbon.	Volatile Matter.	Water.	Moisture.	Ash.	Earthy Matter.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Illinois, Warren Co.	1.23	51.7	43.1	—	—	—	5.2
Bureau "	1.32	57.6	28.8	—	11.2	2.4	—
Mercer "	1.26	54.8	31.2	—	8.4	5.6	—
Indiana, Clay "	1.28	56.5	32.5	8.5	—	2.5	—
Coopriders	1.28	50.5	42.5	3	—	4	—
Pennsylvania, Connellsville	1.28	65	24	4.5	—	6.5	—
Pennsylvania, Youghiogheny	1.3	58.4	35	—	1	5.6	—
Fayette Co.	1.29	58	34	3	—	5	—
Kentucky, Sardric	1.32	51	42.5	2	—	4.5	—
Mud River	1.28	57	37	3.5	—	2.5	—
Ohio, Nelsonville	1.27	58.4	33.05	6.65	—	1.9	—
Colorado, Carbon City	1.21	56.8	34.2	4.5	—	4.5	—
Washington Territory	1.32	58.25	31.75	7	—	3	—

Coke.

Coke.—Coking in a close oven will give an increase of yield of 40 per cent. over coking in heaps, gain in bulk being 22 per cent. Coals when coked in heaps will lose in bulk.

Cannel and Welsh (Cardiff) coals when coked in retorts will gain from 10 to 30 per cent. in bulk and lose 36.5 per cent. in weight.

Relative costs of coal and coke for like results, as developed by an experiment in a locomotive boiler, are as 1 to 2.4.

Evaporative power in furnace of a steam-boiler and under pressure, is from 7.5 to 8.5 lbs. of fresh water per lb.

Bituminous coal will yield from 60 to 80 per cent. of coke. Averaging 66 per cent. It is capable of absorbing 15 to 20 per cent. of moisture.

Heat of combustion lost in coking of bituminous coal 40 per cent.

Charcoal.

Charcoal, properly termed, is not made below a temperature of 536°. The best quality is made from Oak, Maple, Beech, and Chestnut.

Wood will furnish, when properly burned, about 23 per cent. of coal.

Charcoal absorbs, upon an average of the various kinds, from .8 per cent. of water for Beech, to 16.3 for Black Poplar, Oak absorbing about 4.28, and *Pine* 8.9.

Evaporative power, in furnace of a boiler and under pressure, is 5.5 lbs. of fresh water per lb. of coal.

Volume of air chemically required for combustion of 1 lb. of charcoal is, when it consists of 79 carbon, 129 cube feet at 62°.

128 bushels charcoal and 432 lbs. limestone, with 2612 lbs. of ore, will y... ton of pig iron.

luce of Charcoal from Various Woods dried at 300° and Carbonized at 572°. (*M. Violette.*)

Wood.	Weight.	Wood.	Weight.	Wood.	Weight.
	Per Cent.		Per Cent.		Per Cent.
:............	62.8	Larch..........	40.31	Maple..........	33.75
....	46.09	Chestnut.......	36.06	Willow.........	33.74
:h...........	44.25	Apple..........	34.69	Black elder.....	33.61
'............	41.48	Elm............	34.59	Ash............	33.28
ar roots.....	40.9	Birch..........	34.17	Pear...........	31.88

Poplar............ 31.12 per cent.

In a Green or Ordinary State. (*Weight per cent.*)

le........ 23.8	Birch........ 24.1	Oak......... 22.85	Red Pine..... 23
.... 26.7	Elm.......... 25.1	" young... 33.3	White Pine... 23.5
:h........ 21.1	Maple........ 22.9	Poplar....... 20.5	Willow....... 18.6

appears from this that cork, the lightest of woods, yields largest per-centage harcoal, about 63 per cent.; and that poplar yields lowest, about 31 per cent. re does not appear to be any definite relation between density of wood and ıme of yield.

roduce by a slow process of charring is very nearly 50 per cent. greater than by ıick process.

Lignite.

ignite is an imperfect mineral coal. It is distinguished from coal by large proportion of oxygen, being from 13 to 29 per cent. Its specific ,vity ranges from 1.12 to 1.35.

Elements of Various American Lignites. (*W. M. Barr.*)

Location.	Spec. Grav.	Fixed Carbon.	Volatile Matter.	Water.	Ash.	Total Volatile.	Coke.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
ntucky............	1.2	40	23	30	7	53	47
Blandville ...	1.17	31	48	11.5	9.5	59.5	40.5
shington Terr'y....	—	58.25	31.75	7	3	38.75	61.25
ncouver's Island....	—	62	31	4	3	35	65
lorado, Carbon City..	1.27	41.25	46	3.5	9.25	49.5	50.5
Canon City ..	1.28	56.8	34.2	4.5	4.5	38.7	61.3
kansas............	—	34.5	28.5	32	5	60.5	39.5
as, Robertson Co. ..	1.23	45	39.5	11	4.5	50.5	49.5

Asphalt.

Asphalt, alike to Lignite, contains a large proportion of oxygen.

Wood.

Wood, as a combustible, is divided into two classes, the hard, as Oak, Ash, lm, Beech, Maple, and Hickory, and soft, as Pine, Cotton, Birch, Sycamore, ıd Chestnut.

Green wood subjected to a temperature ranging from [illegible] to [illegible] will se 30 to 45 per cent. of its weight.

At a temperature of 300°, Oak, Ash, Elm, and Walnut, in a [illegible] asoned state, lost from 16 to 18 per cent.

Woods contain an average of 56 per cent. of [illegible]

From an analysis of M. Violette it appears that [illegible] me throughout the tree, and that of the bark [illegible] me proportion of carbon 49 per cent. [illegible] ves and small roots have less carb[illegible] 45 per [illegible] d 7 per cent.

ves when dried at 222° lost 60 p[illegible] branches [illegible]

Evaporative power of 1 cube foot of pine wood is equal to that of 1 cube foot of fresh water; or, in the furnace of a steam-boiler and under pressure, it is 4.75 lbs. fresh water for 1 lb. of wood.

Northern Wood.—One cord of *hard* wood and one cord of *soft* wood, such as is used upon Lakes Ontario and Erie, is equal in evaporative effects to 2000 lbs. of anthracite coal.

Western Wood.—One cord of the description used by the river steamboats is equal in evaporative qualities to 12 bushels (960 lbs.) of Pittsburgh coal. 9 cords cotton, ash, and cypress wood are equal to 7 cords of yellow pine.

Solid portion (*lignin*) of all woods, wherever and under whatever circumstances of growth, are nearly similar, specific gravity being as 1.46 to 1.53.

Densest woods give greatest heat, as charcoal produces greater heat than flame.

For every 14 parts of an ordinary pile of wood there are 11 parts of space; or a cord of wood in pile has 71.68 feet of solid wood and 56.32 feet of voids.

Trees in the early part of April contain 20 per cent. more water than they do in the end of January.

Ash.

Proportion of Ash in 100 Lbs. of several Woods.

Woods.	Wood.	Leaves.	Woods.	Wood.	Leaves.
	Per Cent.	Per Cent.		Per Cent.	Per Cent.
Ash	.5	—	Elm	1.88	11.8
Beech	.35	5.4	Oak	.21	4
Birch	.34	5	Pitch Pine	.25	3.15

Peat.

Peat is the organic matter, or soil, of bogs, swamps, and marshes—decayed moss, sedge, coarse grass, etc.—in beds varying from 1 to 40 feet in depth. That near the surface, and less advanced in transformation, is light, spongy, and fibrous, of reddish-brown color; lower down, it is more compact, of a darker brown color; and, in lowest strata, it is of a blackish brown, or almost black, of a pitchy or unctuous surface, the fibrous texture nearly or altogether transformed.

Peat, in its natural condition, contains from 75 to 80 per cent. of water. Occasionally its constituent water amounts to 85 or 90 per cent., in which case peat is of the consistency of mire. It shrinks very much in drying; and its specific gravity varies from .22 to 1.06, surface peat being lightest, and deepest peat densest.

When peat is milled, so that its fibre is broken up, its contraction in drying is much increased, and in this condition it is termed *condensed*.

When ordinarily air dried, it will contain 20 to 30 per cent. of moisture, and when effectively dried at least 15 per cent.

Products of Distillation of Peat.

Water 31.4. Tar 2.8. Gas 36.6. Charcoal 29.2.

The distillation of the tar will yield paraffine, oil, gas, water, and charcoal, and the water acetic acid, wood spirit, and chloride of ammonia.

Evaporative power, in furnace of a steam-boiler and under pressure, is from 3.5 tc 5 lbs. of fresh water per lb. of fuel.

Tan.

[illegible]emlock bark, after having been used in the process of tan[illegible] as a fuel. It consists of the fibre of the bark, and, [illegible]clet, 5 parts of bark produce 4 parts of dry tan; and [illegible] when perfectly dry, or containing but 15 per cent. [illegible] while that of tan in an ordinary state of dryness, con[illegible] of water, is 4284. Weight of water evaporated at 212° [illegible] these units, is 6.31 lbs. for dry, and 4.44 for moist.

Relative Values of different Fuels.

...SCRIPTION.	Lbs. of Steam from Water at 212° by 1 lb. of Fuel.	Relative Evaporative Power for equal Weights.	Relative Evaporative Power for equal Volumes.	Relative Rapidities of Ignition.	Relative Freedom from Waste.	Relative Completeness of Combustion.	Relative Weights.
...thracites.							
...untain, Pa......	10.7	1	1	.505	.633	.725	.945
...eadow..........	9.88	.923	.982	.207	.748	.6	1
...uminous.							
....	8.66	.809	.776	.595	.887	.346	.904
....	8.48	.792	.738	.588	.418	1	.876
....	7.84	.733	.663	.581	1	.333	.852
..., Ind..........	7.34	.686	.616	1	.984	.578	.848
....	6.95	.649	.625	.521	.499	.649	.909
...l, dry..........	4.69	.436	.175	—	16.417	—	—

...ts, Evaporative Powers per Weight and Bulk, ...etc., of different Fuels. (*W. R. Johnson and others.*)

FUEL.	Specific Gravity.	Weight per Cube Foot.	Steam from Water at 212° by 1 lb. of Fuel.	Clinker from 100 lbs.	Cube Feet in a Ton.
...ITUMINOUS.		Lbs.	Lbs.	Lbs.	No.
...nd, *maximum*.....	1.313	52.92	10.7	2.13	42.3
minimum	1.337	54.29	9.44	4.53	41.2
....	1.326	53.22	10.14	—	42.09
...igan.............	1.23	48.3	7.7	—	46.37
...h................	1.324	53.05	9.72	3.4	42.2
...n, *screened*........	1.283	45.72	8.94	3.33	49
average	1.294	54.04	8.39	8.82	41.4
..., Hartley.........	1.257	50.82	8.76	3.14	44
....	1.318	49.25	8.41	6.13	45
...l................	1.252	46.81	8.2	.94	47.8
....	1.338	47.44	7.99	2.25	47.2
...rtley............	1.262	47.88	7.84	1.86	46.7
...ll, Va............	1.285	45.49	7.67	3.86	49.2
..., Ind.............	1.273	47.65	7.34	1.64	47
...alkeith...........	1.519	51.09	7.08	5.63	43.8
....	—	—	5.72	—	—
....	1.231	48.3	—	—	—
...NTHRACITE.					
...ountain...........	1.464	53.79	10.11	3.03	41.6
...provement.......	1.477	53.66	10.06	.81	41.7
...eadow............	1.554	56.19	9.88	.6	39.8
...na...............	1.421	48.89	9.79	1.24	45.8
...eadow, No. 3......	1.61	54.93	9.21	1.01	40.7
....	1.59	55.32	8.93	1.08	40.5
COKE.					
...Virginia...........	1.323	46.64	8.47	5.31	
...n	—	32.7	8.63	10.51	
...nd	—	31.6	8.99	3.55	
...ISCELLANEOUS.				Ash.	
Oak.............	1.5	24	5.5	3.06	
....	.53	30	5	—	
...hel............	1.15	69.1	10.4	2.91	
"	—	65	8.9	—	
...ry............	—	21	4.7	.31	10

Weights and Comparative Values of different Woods.

Woods.	Cord.	Value.	Woods.	Cord.	Value.
	Lbs.			Lbs.	
Shell-bark Hickory ...	4469	1	New Jersey Pine.....	2137	.54
Red-heart Hickory ...	3705	.81	Yellow Pine.........	1904	.43
White Oak...........	3821	.81	White Pine..........	1868	.42
Red Oak.............	3254	.69	Beech...............	—	.7
Virginia Pine.........	2689	.61	Spruce..............	—	.52
Southern Pine........	3375	.73	Hemlock.............	—	.44
Hard Maple..........	2878	.6	Cottonwood..........	—	.33

Liquid Fuels.

Petroleum.

Petroleum is a hydro-carbon liquid which is found in America and Europe. According to analysis of M. Sainte-Claire Deville, composition of 15 petroleums from different sources was found to be practically constant. Average specific gravity was .87. Extreme and average elementary composition was as follows:

Carbon..............	82 to 87.1 per cent.	Average,	84.7 per cent.
Hydrogen...........	11.2 to 14.8 "	"	13.1 "
Oxygen.............	.5 to 5.7 "	"	2.2 "
			100

Its heat of combustion is 20 240, and its evaporative power at 212° 20.33.

Petroleum Oils—Are obtained by distillation from petroleum, and are compounds of carbon and hydrogen, in average proportion of 72.6 and 27.4.

Boiling-point ranges from 86° to 495°.

Schist Oil—Consists of carbon 80.3 parts, hydrogen 11.5, and oxygen 8.2.

Pine Wood Oil—Consists of carbon 87.1 per cent., hydrogen 10.4, and oxygen 2.5.

Coal-gas.

Coal Gas—As furnished by Chartered Gas Co. of London is composed as follows:

	Carbon.	Hydrogen.		Oxygen.	Hydrogen.	Nitrogen.
Olefiant Gas, Bi-carb. hyd. ..	3.096	.434	Hydrogen......	—	51.8	—
Marsh gas, Carb. hyd.	26.445	8.815	Oxygen........	.08	—	—
Carbonic oxide....	3.84	5.11	Nitrogen.......	—	—	.38
			Total........ 100 parts.			

Heat of combustion at 212° 52 961 units, and evaporative power 47.51 lbs.

Coal-gas. (*V. Harcourt.*)

	Carb.	Hyd.	Oxy.	Nit.		Carb.	Hyd.	Oxy.	Nit.
	Per ct.	Per ct.	Per ct.	Per ct.		Per ct.	Per ct.	Per ct.	Per ct.
gas.....	10.5	1.7	—	—	Hydrogen......	—	8.1	—	—
s......	39.7	13.2	—	—	Nitrogen.......	—	—	—	5.8
xide..	5.9	—	7.9	—	Oxygen........	—	—	.3	—
oxide	1.9	—	5	—	Total.......	58	23	13.2	5.8

this gas had a volume of 30 cube feet at 62°; heat of combus[illegible] units: and of one cube foot 756 units, which is equivalent [illegible] of water from 62°, or of .78 lb. from 212° per cube [illegible]

Average Composition of Fuels.

	Specific Grav-ity.	Carbon.	Hydro-gen.	Nitro-gen.	Oxygen.	Sul-phur.	Ash.
BITUMINOUS COALS.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
tralian	1.31	—	—	—	—	.5	8.38
neo	1.28	64.52	4.74	.8	20.75	1.45	7.74
ish, lowest	—	68.72	4.76	—	18.63	1.35	—
head, dry, average	1.18	63.94	8.86	.96	4.7	.32	21.22
i, Conception Bay	1.29	70.55	5.76	.95	13.24	1.98	7.52
Chiriqui	—	38.98	4.01	.58	13.38	6.14	36.91
nel, Wigan	1.23	79.23	6.08	1.18	7.24	1.43	4.84
ıberland, Md.	1.31	93.81	1.82	—	2.77	—	1.6
e, Garesfield	—	97.6	—	—	—	.85	1.55
Durham	—	89.5	—	—	—	1.25	9.25
Average	—	93.44	—	—	—	1.22	5.34
fryn	1.33	88.26	4.66	1.45	.6	1.77	3.26
mosa Island	1.24	78.26	5.7	.64	10.95	.49	3.96
nch, hard	1.32	88.56	4.88	(4.38)		—	2.19
" caking	1.29	87.73	5.08	(5.65)		—	1.54
" long flame	1.3	82.94	5.35	(8.63)		—	3.08
" average*	1.31	85	4.5	(7)		—	3.5
ian, average	—	47.3	—	—	—	—	22.9
" Kotbec	—	90	—	—	—	—	4
agonia	—	62.25	5.05	.63	17.54	1.13	13.4
ısian, Miouchi†	—	91.45	4.5	(4.05)		—	—
ney, S. W.	—	82.39	5.32	1.27	8.32	.07	2.04
int, Wylam	—	74.82	6.18	(5.09)		—	13.91
" Glasgow	—	82.92	5.49	(10.46)		—	1.13
" Cannel, Lancashire	—	83.75	5.66	(8.04)		—	2.55
" " Edinburgh	—	67.6	5.4	(12.43)		—	14.57
" Cherry, Newcastle	—	84.85	5.05	(8.43)		—	1.67
" Caking, Garesfield	—	87.95	5.24	(5.42)		—	1.39
" Ebbro Vale, Welsh	—	89.78	5.15	2.16	.39	1.02	1.5
" Llangenneck "	—	84.97	4.26	1.45	3.5	.42	5.4
ıcouver's Island	—	66.93	5.32	1.02	8.7	2.2	15.83
ANTHRACITES.							
:hracite	1.5	88.54	—	—	—	.52	8.67
nch	1.5	86.17	2.67	(2.85)		—	8.56
ssian	—	96.66	1.35	(1.99)		—	—
WOODS.							
›ch	—	50.17	6.12	1.05	40.38	—	1.77
ch.	—	48.12	6.37	1.15	43.95	—	.48
ϵ	—	48.13	5.25	.82	44.5	—	1.3
ite Pine	—	49.95	6.41	—	43.65	—	.31
ods, average	—	49.7	6.06	1.05	41.3	—	1.8
CHARCOAL.							
ϵ	—	87.68	2.83	—	6.43	—	3.06
e.	—	71.36	5.95	—	22.19‡	—	.4
ple	—	70.07	4.61	—	24.89‡	—	.43
MISCELLANEOUS.							
›halt	1.06	79.18	9.3	(8.72)		—	2.8
nite, perfect	1.29	69.02	5.05	(20.12)		—	5.82
" imperfect	1.25	60.18	5.29	(29.03)		—	5.57
" bituminous	1.18	74.82	7.36	(13.38)		—	4.45
" Colorado	1.28	56.8	—	—	—	—	4.5
" Kentucky	1.2	40	—	—	—	—	7
" Arkansas	—	34.5	—	—	—	—	5
.t, dense	—	61.02	5.77	.81	32.4	—	—
Irish, average	.528	58.18			[illegible]1.21	—	3.43
ent, Warlich	1.15	90.02				1.62	2.[illegible]
Wylam's	1.1	79.91					4[illegible]

*Heat of Combustion of 1 Lb. 14723.
ıcluding Nitrogen.*

Average Composition of Coals and Fuels, Heat of Combustion, and Evaporative Power.

Deduced from analysis and experiments of Messrs. De La Bèche, Playfair, and Pedd.

Coals and Fuels.	Specific Gravity.	Composition. Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Heat of Combustion of 1 lb.	Evaporation from water at 212°.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Units.	Lbs.
Derbyshire and Yorkshire....	1.29	79.68	4.94	1.41	1.01	10.28	2.65	13 860	14.34
Lancashire........	1.27	77.9	5.32	1.3	1.44	9.53	4.88	13 918	14.56
Newcastle	1.26	82.12	5.31	1.35	1.24	5.69	3.77	14 820	15.32
Scotch............	1.26	78.53	5.61	1	1.11	9.69	4.03	14 164	14.77
Welsh............	1.32	83.78	4.79	.98	1.43	4.15	4.91	14 858	15.52
Average of British.	1.28	80.4	5.19	1.21	1.25	7.87	4.05	14 320	14.82
Patent fuels.......	1.17	83.4	4.97	1.08	1.26	2.79	5.93	15 000	15.66
Van Diemen's Land	—	65.8	3.5	1.3	1.1	5.58	22.71	11 320	11.83
Chili..............	—	63.56	5.43	.82	2.5	14.84	13.31	11 030	11.68
Lignite, Trinidad..	—	65.2	4.25	1.33	.69	21.69	6.84	10 438	10.87
" French Alps	1.28	70.02	5.2	—	—	—	3.01	11 790	12.1
" Bitum., Cuba	1.2	75.85	7.25	—	—	—	3.94	14 562	14.96
" Wash. Ter.*.	—	67	4.55	—	1	—	3.1	12 538	12.91
Asphalt...........	1.06	79.18	9.3	—	—	—	2.8	16 655	17.24
Petroleum	.87	84.7	13.1	—	—	2.2	—	20 240	20.33
" oils.....	.75	—	—	—	—	—	—	27 530	28.5
Oak bark Tan, dry.	—	—	—	—	—	—	15	6 100	6.31
" " moist	—	—	—	—	—	—	15	4 284	4.24
Charcoal at 302°...	1.5	47.51	6.12	(O and N 46.29)			.8	8 130	8.4
" " 572°...	1.4	73.24	4.25	(O and N 21.96)			.57	11 861	12.27
" " 810°...	1.71	81.64	4.96	(O and N 15.24)			1.61	14 916	15.43
Peat, dry, average.	.53	58.18	5.96	1.23	—	31.21	3.43	9 951	10.3
" moist,† "	—	43.1	4.3	(O and N 21.4)			3.3	8 917	9.22
Coal-gas..........	42	33.38	66.16	.38	—	.08	—	52 961	47.51

* Water 7. Oxygen and Nitrogen 17.36. † Moisture 27.8. Sulphur .2.

Elements of Fuels not included in Preceding Tables.

Fuel.	Heat of Combustion of 1 lb.	Evaporative Power of 1 lb. at 212°.	Coke produced.	Weight of 1 Cub. Foot.	Volume of 1 Ton.
	Units.	Lbs.	Per cent.	Lbs.	Cube Feet.
Bituminous Coal.					
Welsh......................	14 858	9.05	73	82	42.7
Newcastle..................	14 820	8.01	61	78.3	45.3
Lancashire.................	13 918	7.94	58	79.4	45.2
Scotch.....................	14 164	7.7	54	78.6	42
Boghead....................	14 478	7.87	30.94	—	—
British, average...........	14 133	8.13	61	79.8	44.52
Irish, lowest..............	—	9.85	90	99.6	35.7
Cumberland, Md.............	—	—	83.7	84.93	42.4
American, average..........	—	—	82.5	87.54	43.49
French, average............	14 723	—	64.2	—	40
Australian.................	—	—	68.27	—	—
Anthracite.					
American...................	14 500	—	94.82	93.78	42.35
French.....................	14 038	—	88.83	—	—
Miscellaneous.					
Warlich's fuel.............	16 495	—	—	73.5	34.5
Coke...............Mickley	15 600	—	—	—	80
ginia, average.............	13 550	14.02	—	45	69.8
oal........................	12 325	—	—	—	12.76
perfect....................	11 678	12.1	47	—	—
imperfect..................	9834	10.18	37.5	—	—
Russian....................	15 837	—	—	—	—
....	16 555	17.24	9	—	11
y, average.................	7792	8.07	—	—	[illegible]

Miscellaneous.

Experiments undertaken by Baltimore and Ohio R. R. Co. determined ·aporating effect of 1 ton of Cumberland coal equal to 1.25 tons of anthrate, and 1 ton of anthracite to be equal to 1.75 cords of pine wood; also at 2000 lbs. of Lackawanna coal were equal to 4500 lbs. best pine wood.

One lb. of anthracite coal in a cupola furnace will melt from 5 to 10 lbs. of cast on; 8 bushels bituminous coal in an air furnace will melt 1 ton of cast iron.

Small coal produces about .75 effect of large coal of same description.

Experiments by Messrs. Stevens, at Bordentown, N. J., gave following results:

Under a pressure of 30 *lbs.*, 1 lb. pine wood evaporated 3.5 to 4.75 lbs. of water. lb. Lehigh coal, 7.25 to 8.75 lbs.

Bituminous coal is 13 per cent. more effective than coke for equal weights; and England effects are alike for equal costs.

Radiation from Fuel.—Proportion which heat radiated from incandescent fuel ars to total heat of combustion is,

From Wood.................... .29 | From Charcoal and Peat........ .5

Least consumption of coal yet attained is 1.5 lbs. per IHP. It usually varies in ferent engines from 2 to 8 lbs.

Volume of pine wood is about 5.5 times as great as its equivalent of bituminous al.

GRAVITATION.

Gravity is an attraction common to all material substances, and ey are affected by it directly, in exact proportion to their mass, and versely, as square of their distance apart.

This attraction is termed *terrestrial gravity*, and force with which a dy is drawn toward centre of Earth is termed the *weight* of that body.

Force of gravity differs a little at different latitudes: the law of variation, wever, is not accurately ascertained; but following theorems represent it ry nearly:

$$\left.\begin{array}{l} g'\,(1-.002\,837\ \cos.\ 2\ \text{lat.}) \\ g'\,(1+.002\,837),\ \text{at the poles} \\ g'\,(1-.002\,837),\ \text{at the equator} \end{array}\right\} = g.$$

g′ representing force of gravity at latitude 45°, *and g force at other places.*

Or, $32.171\ (\text{lat. } 45^\circ)\ (1+.005\,133\ \sin.\ L)\left(1-\frac{2\,H}{R}\right)=g.$ L *representing latitude, height of elevation above level of sea, and* R *radius of Earth, both in feet.*

Note.—If 2 L exceeds 90°, put cos. 180 — 2 L, and R at Equator = 20926062, at les 20853429, and mean 20889746.

Illustration.—What is force of gravity at latitude 45°, at an elevation of 209 et, and radius = 20900000 feet?

$$.171\ (1+.005\,133\ \sin.\ 45^\circ)\left(1-\frac{2\,H}{20\,900\,000}\right)=32.171\times 1.003\,63\times .999\,98=32.287.$$

Gravity at Various Locations at Level of Sea.

uator	32.088	New York	32.161	London	32.189
ashington	32.155	Lat. 45°	32.171	Poles	32.253

In bodies descending freely by their own weight, their velocities are as nes of their *descent, and spaces* passed through as square of the times.

Times, then, being 1, 2, 3, 4, etc., *Velocities* will be 1, 2, 3

aces passed through will be as square of the velocit

se times, as 1, 4, 9, 16, etc.; and *spaces* for each time

A body falling freely will descend through 16.0833 feet in first second of time, and will then have acquired a velocity which will carry it through 32.166 feet in next second.

If a body descends in a curved line, it suffers no loss of velocity, and the curve of a cycloid is that of quickest descent.

Motion of a falling body being uniformly accelerated by gravity, motion of a body projected vertically upwards is uniformly retarded in same manner.

A body projected perpendicularly upwards with a velocity equal to that which it would have acquired by falling from any height, will ascend to the same height before it loses its velocity. Hence, a body projected upwards is ascending for one half of time it is in motion, and descending the other half.

Various Formulas here given are for Bodies Projected Upwards or Falling Freely, in Vacuo.

When, however, weight of a body is great compared with its volume, and velocity of it is low, deductions given are sufficiently accurate for ordinary purposes.

In considering action of gravitation on bodies not far distant from surface of the Earth, it is assumed, without sensible error, that the directions in which it acts are parallel, or perpendicular to the horizontal plane.

A distance of one mile only produces a deviation from parallelism less than one minute, or the 6oth part of a degree.

Relation of Time, Space, and Velocities.

Time from Beginning of Descent.	Velocity acquired at End of that Time.	Squares of Time.	Space fallen through in that Time.	Spaces for this Time.	Space fallen through in last Second of Time.
Seconds.	Feet.	Seconds.	Feet.	No.	Feet.
1	32.166	1	16.083	1	16.08
2	64.333	4	64.333	3	48.25
3	96.5	9	144.75	5	80.41
4	128.665	16	257.33	7	112.58
5	160.832	25	402.08	9	144.75
6	193	36	579	11	176.92
7	225.166	49	788.08	13	209.08
8	257.333	64	1029.33	15	241.25
9	289.5	81	1302.75	17	273.42
10	321.666	100	1608.33	19	305.58

and in same manner this Table may be continued to any extent.

Velocity acquired d[illegible] to given Height of Fall and Height [illegible] to given Velocity.

$8.04\sqrt{h} = v$; $.2\,t = v$; $\frac{v^2}{64.4} = h$; and $16.083\,t^2 = h$.

h representing height of fall in feet, v velocity acquired in feet per second, and t time of fall in seconds.

To Compute Action of Gravity.

Time.

When Space is given. RULE.—Divide space by 16.083, and square root of quotient will give time.

EXAMPLE.—How long will a body be in falling through 402.08 feet?

$\sqrt{402.08 \div 16.083} = 5$ seconds.

[illegible]s given. RULE.—Divide given velocity by 32.166, [illegible] time.

[illegible] must a body be in falling to acquire a velocity of [illegible]

800 ÷ 32.166 = 24.87 seconds.

Velocity.

Vhen Space is given. RULE.—Multiply space in feet by 64.333, and are root of product will give velocity.

XAMPLE.—Required velocity a body acquires in descending through 579 feet.

$$\sqrt{579 \times 64.333} = 193 \textit{ feet.}$$

Velocity acquired at any period is equal to twice the mean velocity during period.

LUSTRATION.—If a ball fall through 2316 feet in 12 seconds, with what velocity it strike?

$$2316 \div 12 = 193, \textit{ mean velocity}, \text{ which} \times 2 = 386 \textit{ feet} = \textit{velocity.}$$

Vhen Time is given. RULE.—Multiply time in seconds by 32.166, and duct will give velocity.

XAMPLE.—What is velocity acquired by a falling body in 6 seconds?

$$32.166 \times 6 = 192.996 \textit{ feet.}$$

Space.

Vhen Velocity is given. RULE.—Divide velocity by 8.04, and square of tient will give distance fallen through to acquire that velocity.

)r, Divide square of velocity by 64.33.

XAMPLE.—If the velocity of a cannon-ball is 579 feet per second, from what ht must a body fall to acquire the same velocity?

$$579 \div 8.04 = 72.014, \text{ and } 72.014^2 = 5186.02 \textit{ feet.}$$

Vhen Time is given. RULE.—Multiply square of time in seconds by 083, and it will give space in feet.

XAMPLE.—Required space fallen through in 5 seconds.

$$5^2 = 25, \text{ and } 25 \times 16.083 = 402.08 \textit{ feet.}$$

istance fallen through in feet is very nearly equal to square of time in fourths second.

LUSTRATION I.—A bullet dropped from the spire of a church was 4 seconds in hing the ground; what was height of the spire?

$$4 \times 4 = 16, \text{ and } 16^2 = 256 \textit{ feet.}$$

y Rule, $4 \times 4 \times 16.0833 = 257.33$ *feet.*

—A bullet dropped into a well was 2 seconds in reaching bottom; what is the th of the well?

$$\text{Then } 2 \times 4 = 8, \text{ and } 8^2 = 64 \textit{ feet.}$$

y Rule, $2 \times 2 \times 16.0833 = 64.33$ *feet.*

y Inversion.—In what time will a bullet fall through 256 feet?

$$\sqrt{256} = 16, \text{ and } 16 \div 4 = 4 \textit{ seconds.}$$

Space fallen through in last Second of Fall.

Vhen Time is given. RULE.—Subtract half of a second from time, and ltiply remainder by 32.166.

XAMPLE.—What is space fallen through in last second of time, of a body falling 10 seconds?

$$10 - .5 \times 32.166 = 305.58 \textit{ feet.}$$

Promiscuous Examples.

. If a ball is 1 minute in falling, how far will it fall in last second?

pace fallen through = square of time, and 1 *minute* = 60 seconds.

$$60^2 \times 16.083 = 57\,898 \textit{ feet} \text{ for } 60 \text{ seconds.}$$
$$59^2 \times 16.083 = \underline{55\,984} \quad \text{“} \quad \text{“} \quad \underline{59} \quad \text{“}$$
$$1\,914 \qquad\qquad 1$$

ompute time of generating a velocity of 193 feet per second, and whole st ded.

$$193 \div 32.166 = 6 \textit{ seconds}; \; 6^2 \times 16.083 = 579 \textit{ feet.}$$

3. If a body was to fall 579 feet, what time would it be in falling, and would it fall in the last second?

$$\sqrt{\frac{579 \times 2}{32.166}} = \sqrt{36} = 6 \text{ seconds, and } 6 - .5 \times 32.166 = 5.5 \times 32.166 = 176.\text{ç}$$

Formulas to determine the various Element

1. $T = \sqrt{\frac{S}{.5\,g}};\ = \frac{V}{g};\ = \frac{2\,S}{V};\ = \sqrt{\frac{2\,S}{g}};\ = \frac{h}{g} + .5.$

2. $S = \left(\frac{V}{.25\,g}\right)^2;\ = \frac{V^2}{2\,g};\ = \frac{V\,T}{2};\ = \frac{g\,T^2}{2};\ = T^2 .5\,g.$ 3. $h = ($

4. $V = \sqrt{S \times 2\,g};\ = T\,g;\ = 2\sqrt{.5\,g\,S};\ = \frac{2\,S}{T}.$

T *representing time of falling in seconds*, V *velocity acquired in feet pe* S *space or vertical height in feet*, h *space fallen through in last second*, g 32 .5 g *and* .25 g *representing* 16.083 *and* 8.04.

Retarded Motion.

A body projected vertically upward is affected inversely to its when falling freely and directly downward, inasmuch as a like cause it in one case and accelerates it in the other.

In air a ball will not return with same velocity with which it star *vacuo* it would. Effect of the air is to lessen its velocity both ascend descending. Difference of velocities will depend upon relative specif ity of ball and density of medium through which it passes. Thus, weight of ball, greater its velocity.

To Compute Action of Gravity by a Body Proj Upward or Downward with a given Veloc Space.

When projected Upward. RULE.—From the product of the given and the time in seconds subtract the product of 32.166, and half th of the time, and the remainder will give the space in feet.

Or, Square velocity, divide result by 64.33, and quotient will gi in feet.

EXAMPLE.—If a body is projected upward with a velocity of 96.5 feet pe through what space will it ascend before it stops?

$$96.5 \div 32.166 = 3 \textit{ seconds} = \textit{time to acquire this velocity.}$$

$$\text{Then, } 96.5 \times 3 - \left(32.166 \times \frac{3^2}{2}\right) = 289.5 - 144.75 = 144.75 \textit{ feet.}$$

Time.

RULE.—Divide velocity in feet by 32.166, and quotient will give seconds.

EXAMPLE.—Velocity as in preceding example.

$$96.5 \div 32.166 = 3 \textit{ seconds.}$$

Velocity.

—Multiply time in seconds by 32.166, and product will give r second.

—Time as in preceding example.

$$3 \times 32.166 = 96.5 \textit{ feet velocity.}$$

en through in last Second.

time, multiply remainder by 32.166, ar d.

ample.

$$.5 \times 32.166 = 80.416 \text{ feet.}$$

When projected Downward.

Space.

RULE.—Proceed as for projection upwards and take sum of products.

EXAMPLE 1.—If a body is projected downward with a velocity of 96.5 feet per second, through what space will it fall in 3 seconds?

$$96.5 \times 3 + \left(32.166 \times \frac{3^2}{2}\right) = 289.5 + 144.75 = 434.25 \textit{ feet.}$$

$$\text{Or, } t^2 \times 16.083 + \overline{v \times t} = s.$$

2.—If a body is projected downward with a velocity of 96.5 feet per second through what space must it descend to acquire a velocity of 193 feet per second?

$96.5 \div 32.166 = 3$ *seconds, time to acquire this velocity.*
$193 \div 32.166 = 6$ *seconds, time to acquire this velocity.*

Hence $6 - 3 = 3$ *seconds, time of body falling.*

Then $96.5 \times 3 = 289.5 =$ *product of velocity of projection and time.*

$16.083 \times 3^2 = 144.75 =$ *product of* 32.166, *and half square of time.*

Therefore $289.5 + 144.75 = 434.25$ *feet.*

Time.

RULE.—Subtract space for velocity of projection from space given, an remainder, divided by velocity of projection, will give time.

EXAMPLE.—In what time will a body fall through 434.25 feet of space, when pro jected with a velocity of 96.5 feet?

Space for velocity of $96.5 = 144.75$ *feet.*

$$\text{Then, } 434.25 - 144.75 \div 96.5 = 289.5 \div 96.5 = 3 \textit{ seconds.}$$

Velocity.

RULE.—Divide twice space fallen through in feet by time in seconds.

EXAMPLE.—Elements as in preceding example.

Space fallen through when projected at velocity of 96.5 *feet* = 144.75 *feet, and* 434.2 *feet* = *space fallen through in* 3 *seconds.*

Then, $144.75 + 434.25 = 579$ *feet* space fallen through, and $\sqrt{579 \div 16.083} =$ *seconds.*

Hence, $579 \times 2 \div 6 = 1158 \div 6 = 193$ *feet.*

Space Fallen through in last Second.

RULE.—Subtract .5 from time, multiply remainder by 32.166, and produc will give space in feet per second.

EXAMPLE.—Elements as in preceding example.

$$6 - .5 \times 32.166 = 5.5 \times 32.166 = 176.91 \textit{ feet.}$$

Ascending bodies, as before stated, are retarded in same ratio that descendir bodies are accelerated. Hence, a body projected upward is ascending for one ha of the time it is in motion, and descending the other half.

ILLUSTRATION 1.—If a body projected vertically upwards return to earth in 1 seconds, how high did it ascend?

The body is half time in ascending. $12 \div 2 = 6$.

Hence, by Rule, p. 489, $6^2 \times 16.083 = 579$ *feet* = *product of square of time a* 16.083.

2.—If a body is projected upward with a velocity of 96.5 feet per second, it required to ascertain point of body at end of 10 seconds.

$96.5 \div 32.166 = 3$ *seconds, time to acquire this velocity,* and $3^2 \times 16.083 = 144.$ *feet, height body reached with its initial velocity.*

Then $10 - 3 = 7$ *seconds left for body to fall in.*

Hence, by Rule, as in preceding example, $7^2 \times 16.083 = 788.07$, and 78 $144.75 = 643.32$ *feet* = *distance below point of projection.*

Or, $10^2 \times 16.083 = 1608.3$ *feet, space fallen through under* the effect of gra 96.5 × 10 = 965 *feet, space if gravity did not act.* Hence $1608.3 - 965 = 6$

3.—A body is projected vertically with a velocity of 135 feet; what velocity will it have at 60 feet?

$135^2 \div 64.33 = 283.3$ *feet space projected at that velocity*, $135 \div 32.16 = 4.197$ *seconds = time of projection*, and $283.3 - 60 = 223.3 =$ *space to be passed through after attainment of* 60 *feet*. Hence, $\sqrt{223.3 \times 64.33} = 119.85$ *feet velocity*, and $223.3 + 60 = 283.3$ *feet*.

By Inversion.—Velocity 119.85. Hence, $\frac{119.85^2}{64.33} = 223.3$ *feet space*, and $283.3 - 223.3 = 60$ *feet*.

Formulas to Determine Elements of Retarded Motion.

1. $v = V - \overline{g\,t}$.
2. $V = \frac{S}{t} - \frac{g\,t}{2}$.
3. $V = v + \overline{g\,t}$.
4. $t' = \frac{V \div 2}{g}$.
5. $S = V\,t - \frac{g\,t^2}{2}$.
6. $h = T - \overline{t - t'} - .5\,g$.
7. $S = t\,v + \frac{g\,t^2}{2}$.
8. $t = \frac{V - v}{g}$.
9. $t = \frac{V}{g} - \sqrt{\frac{V^2}{g^2} - \frac{2\,S}{g}}$.

v representing velocity at expiration of time, t any less time than T, *t′ less time than t, s space through which a body ascends in time t,* V, T, S, *and h as in previous formulas*, page 490.

Illustration.—A body projected upwards with a velocity of 193 feet per second, was arrested in 5 seconds.

$T = 6,\ t' = 1.$

1. What was its velocity when arrested? (1.)
2. What was the time of its passing through 562.92 feet of space? (8.)
3. What space had it passed through? (5.)
4. What was the time of its projection, when it had a velocity of 96.5 feet? (4.)
5. What was the height it was projected in the last second of time? (6.)

1. $193 - \overline{32.166 \times 5} = 32.17$ *feet*.
3. $32.17 + \overline{32.166 \times 5} = 193$ *velocity*.
2. $\frac{562.92}{5} + \frac{32.166 \times 5}{2} = 193$ *velocity*.
4. $\frac{193 \div 2}{32.166} = \frac{96.5}{32.166} = 3$ *seconds*.
5. $193 \times 5 - \frac{32.166 + 5^2}{2} = 562.92$ *feet*.
6. $6 - \overline{5 - 1} - .5 \times 32.166 = 48.25$ *feet*.
7. $S = t\,v + \overline{g\,t^2 \div 2} = 562.92$ *feet*.
8. $\frac{193 - 32.17}{32.166} = 5$ *seconds*.
9. $\frac{193}{32.166} - \sqrt{\frac{193^2}{32.166^2} - \frac{2 \times 562.92}{32.166}} = 6 - \sqrt{36 - 35} = 5$ *seconds*.

Gravity and Motion at an Inclination.

If a body freely descend at an inclination, as upon an inclined plane, by force of gravity alone, the velocity acquired by it when it arrives at termination of inclination is that which it would acquire by falling freely · vertical height thereof. Or, velocity is that due to height of in- · of the plane.

·cupied in making descent is greater than that due to height, as ·gth of its inclination, or distance passed, to its height.

·ently, times of descending different inclinations or planes of like · to one another as lengths of the inclinations or planes.

·ich a body descends upon an inclination, *when descending by* spe· ·l freely fall in same time as height of inclination ·· ·eing same, times will be inversely in this pro-

it suffers no loss of velocity.

· from rest, from same point, one upon a · freely, their velocities at all equal heights ·al.

LUSTRATION.—What distance will a body roll down an inclined plane 300 feet ; and 25 feet high in one second, by force of gravity alone?

As $300 : 25 :: 16.083 : 1.34025$ *feet*.

ence, if proportion of height to length of above plane is reduced from 25 to 300 5 to 600, the time required for body to fall 1.34025 feet would be determined as ›ws:

s $25 : 600 :: 1.34025 : 32.166$, and $32.166 = 16.083 \times 2 =$ *twice time or space in* :*h it would fall freely required for one half proportion of height to length.*

$$\text{Or, as } \frac{300}{25} : \frac{600}{25} :: 1.34025 : 32.166, \textit{ as above.}$$

mpelling or accelerating force by gravitation acting in a direction paral- to an inclination, is less than weight of body, in ratio of height of in- ation to its length. It is, therefore, inversely in proportion to length of ination, when height is the same.

'ime of descent, under this condition, is inversely in proportion to accel- :ing force.

f, for instance, length of inclination is five times height, time of making :ly descent at inclination by gravitation is five times that in which a y would freely fall vertically through height; and impelling force down ination is .2 of weight of body.

Vhen bodies move down inclined planes, the accelerating force is ex- ssed by $h \div l$, *quotient of height ÷ length of plane;* or, what is equivalent :eto, sine of inclination of plane, *i. e.*, sin. a.

.LUSTRATION.—An inclined plane having a height of one half its length, the space :n through in any time would be *one half of that which it would fall freely.*

elocity which a body rolling down such a plane would acquire in 5 seconds is .16 feet.

hus, $32.166 \times 5 = 160.833$ feet, and an inclined plane, having a height one half ts length, has an angle or sine of 30°. Hence, sin. $30° = .5$, and $160.833 \times .5 =$ .16 *feet.*

›rmulas to Determine various Elements of Gravita- tion on an Inclined Plane.

1. $S = .5\, g\, T^2 \sin. a; \; = \dfrac{V^2}{2\, g \sin. a}; \; = .5\, T\, V.$ 4. $V = \overline{v \mp g\, T \sin. a}.$

2. $V = g\, T \sin. a; \; = \sqrt{(2\, g\, S \sin. a)}; \; = \dfrac{2\, S}{T}.$ 6. $H = \dfrac{l^2}{.5\, g\, T^2}.$

3. $T = \sqrt{\left(\dfrac{2\, S}{g \sin. a}\right)}; \; = \dfrac{2\, S}{V}; \; = .25\sqrt{\dfrac{l^2}{H}}; \; = \dfrac{l}{4\sqrt{H}}.$ 7. $l = 4\, T\sqrt{H}.$

5. $S = \overline{V\, T \mp .5\, g\, T^2 \sin. a}.$ Or, $\dfrac{V^2}{2\, g \sin. a}.$

representing velocity of projection in feet per second, S *space or vertical height* :*locity and projection, a angle of inclination of plane, l length, and* H *height of ne.*

LUSTRATION.—Assume elements of preceding illustration. $V = 80.416$, $T = 5$, $H = 201.04$.

$.5 \times 32.166 \times 5^2 \times .5 = 201.04$ *feet.* 2. $32.166 \times 5 \times .5 = 80.416$ *feet.*

3. $\sqrt{\left(\dfrac{2 \times 201.04}{32.166 \times .5}\right)} = \sqrt{\left(\dfrac{402.08}{16.083}\right)}\; \sqrt{25} = 5$ *seconds.*

$\dfrac{283.42^2}{.5 \times 16.083 \times 5^2} = 201.04$ *feet.* 7. $4 \times 5 \times \sqrt{201.04} = 28$

projected downward with an initial velocity of 16.083 feet per sec

$16.083 + \overline{32.166 \times 5 \times .5} = 96.5$ *feet.*

$80.416 + 16.083 \times 5 - \overline{.5 \times 32.166 \times 5^2 \times .5} = 281.46$ feet.

ILLUSTRATION.—What time will it take for a ball to roll 38 feet down an inclined plane, the angle $a = 12^\circ\ 20'$, and what velocity will it attain at 38 feet from its starting-point?

$$T = \sqrt{\frac{2\,S}{g\ \sin.\ a}} = \sqrt{\frac{2 \times 38}{32.166 \times .2136}} = 3.33\ seconds. \quad V = g\ T\ \sin.\ a = 32.166 \times 3.33 \times .2136 = 22.88\ feet\ per\ second.$$

When a body is projected upward it is retarded in the same ratio that a descending body is accelerated.

ILLUSTRATION.—If a body is projected up an inclined plane having a length of twice its height, at a velocity of 96.5 feet per second,

Then, $T = 96.5 \div 32.166 = 3$ *seconds.* $S = .5\ 32.166 \times 3^2 \times .5 = 72.375$ *feet.* $v = 32.166 \times 3 \times .5 = 48.25$ *feet.*

Inclined Plane.

Problems on descent of bodies on inclined planes are soluble by formulas 1 to 9, page 495, for relations of accelerating forces. As a preliminary step, however, accelerating force is to be determined by multiplying weight of descending body by height of plane, and dividing product by length of plane.

ILLUSTRATION.—If a body of 15 lbs. weight gravitate freely down an inclined plane, length of which is five times height, accelerating force is $15 \div 5 = 3$ lbs. If length of plane is 100 feet and height 20, velocity acquired in falling freely from top to bottom of plane would be

$$v = 8\sqrt{\frac{3 \times 100}{15}} = 8\ \sqrt{20} = 35.776\ feet.$$

Time occupied in making descent,

$$t = .25\sqrt{\frac{15 \times 100}{3}} = .25\ \sqrt{500} = 5.59\ seconds.$$

Whereas, for a free vertical fall through height of 20 feet, time would be,

$$t = \frac{35.776}{32.166} = 1.118\ seconds,$$

which is .2 of time of making descent on inclined plane.

Velocities acquired by bodies in falling down planes of like height will all be equal when arriving at base of plane.

When Length of an Inclined Plane and Time of Free Descent are given.

RULE.—Divide square of length by square of time in seconds and by 16; the quotient is height of inclined plane.

EXAMPLE.—Length of plane is 100 feet, and time of descent is 5.59 seconds; then vertical height of descent is

$$\frac{100^2}{5.59^2 \times 16.08} = 20\ feet.$$

Accelerated and Retarded Motion.

If an Accelerating or Retarding force is greater than gravity, that is weight of the [illegible], the constant, g, or 32.166, is to be varied in proportion thereto, [illegible] is it is to be multiplied by the accelerating force, and product [illegible] weight of body.

The [illegible] *accelerating* [illegible] *and w weight of body.*

[illegible], or [illegible] $\frac{[illegible]083\,f}{w}$ become the constants.

[illegible] formu[illegible] en given for action of gravity [illegible] [illegible]rmly accelerating or retarding [illegible] [illegible]apted to the force.

Average Velocity of a Moving Body uniformly Accelerated or Retarded.

Average velocity of a moving body uniformly accelerated or retarded, during a given time or in a given space, is equal to half sum of initial and final velocities; and if body begin from a state of rest or arrive at a state of rest, its average speed is half the final or initial velocity, as the case may be.

Thus, in example of a ball rolling, initial speed or velocity is, in either case, 60 feet per second, and terminal speed is nothing; average speed is therefore $\frac{60+0}{2}$, namely, one half of that, or 30 feet per second.

When a cannon-ball is projected at an angle to horizon, there are two forces acting on it at same time—viz., force of charge, which propels it uniformly in a right line, and force of gravity, which causes it to fall from a right line with an accelerated motion; these two motions (uniform and accelerated) cause the ball to move in the curved line of a Parabola.

Formulas for Flight of a Cannon-ball.

$$V = 2800\sqrt{\frac{P}{w}};\quad P = \frac{w\,V^2}{7\,840\,000};$$

$$b = \frac{V^2 \sin. a, \cos. a}{g};\quad t = \frac{V \sin. a}{g};\quad h = \frac{V^2 \sin.^2 a}{2g}.$$

w representing weight of ball and P *of powder in lbs.; t time of flight in seconds; b horizontal range, and h vertical height of range of projection of ball in feet.*

ILLUSTRATION.—A cannon loaded to give a ball a velocity of 900 feet per second, the angle $a = 45°$; what is horizontal range, the time t and height of range h?

$$b = \frac{900^2 \times \sin. 45° \times \cos. 45°}{32.166} = \frac{900^2 \times .5}{32.166} = 12\,590 \textit{ feet.}$$

$$t = \frac{900 \times .7071}{32.166} = 19.78 \textit{ seconds};\quad h = \frac{900^2 \times .7071^2}{2 \times 32.166} = 6295 \textit{ feet.}$$

NOTE.—As distance b will be greatest when angle $a = 45°$, product of *sine* and *cosine* is greatest for that angle. Sin. $45° \times$ cos. $45° = .5$.

24 lb. ball with a velocity of 2000 feet per second at 45° range 7300 feet.

General Formulas for Accelerating and Retarding Forces.

1. $V = \frac{g\,f\,t}{w}$. 2. $S = \frac{.5\,g\,f\,t^2}{w}$. 3. $t = \frac{w\,V}{g\,f}$. 4. $S = \frac{w\,V^2}{2\,g\,f}$.

5. $t = .25\sqrt{\frac{w\,S}{f}}$. 6. $V = 8\sqrt{\frac{f\,S}{w}}$.

7. $f = \frac{w\,V^2}{2\,g\,S}$. 8. $f = \frac{w\,V}{t\;32.2}$. 9. $w = \frac{g\,f\,t}{V}$.

NOTE 1.—When accelerating or retarding force bears a simple ratio to weight of body, the ratio may, for facility of calculation, be substituted in the quantities representing modified constants, for force and weight. Thus, if accelerating force is a tenth part of weight, then ratio is 1 to 10, and $\frac{32.166}{10} = 3.2166$; or, $\frac{16.083}{10} = 1.6083$, and $\frac{64.333}{10} = 6.4333$; and these quotients may be substituted for 16.083, 32.166, and 64.333 respectively, in formulas for action of gravity 1 to 9, to fit them for computation in an accelerating or retarding force one-tenth of gravity.

2.—Table, page 488, giving relations of velocity and height of falling bodies may be employed in solving questions of accelerating force general.

EXAMPLE.—*A ball weighing* 10 lbs. is projected with an initial v... *per second on a level plane,* and frictional resistance to its motion is ... *distance will it traverse before* it comes to a state of rest? By formula

$$\therefore \frac{10 \text{ lbs.} \times 60^2}{64.333 \times 1 \text{ lb.}} = 559.59 \textit{ feet.}$$

Again, same result may be arrived at, according to Note 1, by multiplyi stant 64.333, in Rule, page 494, for gravity, by ratio of force and weight, w this case is $\frac{1}{10}$, and $64.333 \times \frac{1}{10} = 6.4333$. Substituting 6.4333 for 64.333 rule, formula becomes

$$S = \frac{V^2}{6.4333} = \frac{60^2}{6.4333} = 559.59 \textit{ feet.}$$

The question may be answered more directly by aid of table for falling page 488. Height due to a velocity of 60 feet per second, is 55.9 feet; wh be multiplied by inverse ratio of accelerating force and weight of body, or $\frac{1}{1}$ that is,

$$55.9 \times 10 = 559 \textit{ feet.}$$

If the question is put otherwise—What space will a weight move over l comes to a state of rest, with an initial velocity of 60 feet per second, allow tion to be one tenth weight? The answer is that friction, which is retardi being one tenth of weight, or of gravity, space described will be 10 times as is necessary for gravity, supposing the weight to be projected vertically up bring it to a state of rest. The height due to velocity being 55.9 feet; then

$$55.9 \times 10 = 559 \textit{ feet.}$$

Average velocity of a moving body, uniformly accelerated or retarded given period or space, is equal to half sum of initial and final velocities.

To Compute Velocity of a Falling Stream of Wat Second at End of any given Time.

When Perpendicular Distance is given.

EXAMPLE.—What is the distance a stream of water will descend on an plane 10 feet high, and 100 feet long at base, in 5 seconds?

$$5^2 \times 16.083 = 402.08 \textit{ feet} = \textit{space a body will freely fall in this time.}$$

Then, as $100 : 10 :: 402.08 : 40.21$ *feet = proportionate velocity on a plan dimensions to velocity when falling freely.*

Miscellaneous Illustrations.

1.—What is the space descended vertically by a falling body in 7 seconds

$$S = .5\, g \times t^2. \quad \text{Then } 16.083 \times 7^2 = 788.067 \textit{ feet.}$$

2.—What is the time of a falling body descending 400 feet, and velocity at end of that time?

$$t = \frac{v}{g}. \quad \text{Then } \frac{160.4}{32.166} = 4.98 \textit{ sec.} \quad v = \sqrt{2\, g \times S}. \quad \text{Then } \sqrt{64.333 \times 400} = 1$$

3.—If a drop of rain fall through 176 feet in last second of its fall, how h the cloud from which it fell?

$$S = \frac{h^2}{2\, g}. \quad \text{Then } \frac{176^2}{64.166} = 482.75 \textit{ feet.}$$

4.—If two weights, one of 5 lbs. and one of 3, hanging freely over a sh set free, how far will heavier one descend or lighter one rise in 4 seconds

$$\frac{5-3}{5+3} \times 16.083 \times 4^2 = \frac{2}{8} \times 257.328 = 64.33 \textit{ feet.}$$

5.—If length of an inclined plane is 100 feet, and time of descent of a bo seconds, what is vertical height of plane or space fallen through?

$$\frac{100^2}{6^2 \times .5\, g} = \frac{10\,000}{579} = 17.27 \textit{ feet.}$$

6.—If a bullet is projected vertically with a velocity of 135 feet per secon velocity will it have at 60 feet?

$$\text{Formula 9, page 492.} \quad \frac{135}{32.166} - \sqrt{\frac{135^2}{32.166^2} - \frac{2 \times 60}{32.166}} = .47 \text{ fe}$$

GUNNERY.

heavy body impelled by a force of projection describes in its flight ack a parabola, *parameter* of which is four times height due to ity of projection.

locity of a shot projected from a gun varies as square root of ;e directly, and as square root of weight of shot reciprocally.

To Compute Velocity of a Shot or Shell.

LE.—Multiply square root of triple weight of powder in lbs. by 1600; product by square root of weight of shot; and quotient will give ve- in feet per second.

MPLE.—What is velocity of a shot of 196 lbs., projected with a charge of 9 lbs. rder?

$$\sqrt{9 \times 3} \times 1600 \div \sqrt{196} = 8320 \div 14 = 594.3 \textit{ feet.}$$

Compute Range for a Charge, or Charge for a Range.

ien Range for a Charge is given.—Ranges have same proportion as es of powder; that is, as one range is to its charge, so is any other to its charge, elevation of gun being same in both cases. *Consequently,*

To Compute Range.

LE.—Multiply range determined by charge in lbs. for range required, product by given charge, and quotient will give range required.

MPLE.—If, with a charge of 9 lbs. of powder, a shot ranges 4000 feet, how far charge of 6.75 lbs. project same shot at same elevation?

$$4000 \times 6.75 \div 9 = 3000 \textit{ feet.}$$

To Compute Charge.

LE.—Multiply given range by charge in lbs. for range determined, product by range determined, and quotient will give charge required.

MPLE.—If required range of a shot is 3000 feet, and charge for a range of 4000 is been determined to be 9 lbs. of powder, what is charge required to project shot at same elevation?

$$3000 \times 9 \div 4000 = 6.75 \textit{ lbs.}$$

Compute Range at one Elevation, when Range for another is given.

LE.—As sine of double first elevation in degrees is to its range, so is f double another elevation to its range.

MPLE.—If a shot range 1000 yards when projected at an elevation of 45°, how ll it range when elevation is 30° 16′, charge of powder being same?

Sine of $45° \times 2 = 100\,000$; sine of $30° 16' \times 2 = 87\,064$.

n, as $100\,000 : 1000 :: 87\,064 : 870.64$ *feet.*

Compute Elevation at one Range, when Elevation for another is given.

LE.—As range for first elevation is to sine of double its elevation, so ge for elevation required to sine for double its elevation.

MPLE.—If range of a shell at 45° elevation is 3750 feet, at what elevation a gun be set for a shell to range 2810 feet with a like charge of powder?

Sine of $45° \times 2 = 100\,000$.

n, as $3750 : 100\,000 :: 2810 : 74\,933 =$ *sine for double* $= 24° 16'$.

Approximate Rule for Time of

der *4000 yards, velocity* of projectile 900 f ... under ards, *velocity 800 feet*; and over 6000 yard

and Howitzers take their denomination fro *round numbers,* up to the 42-pounder; larg *from diameter* of their bore.

Initial Velocity and Ranges of Shot and Shells.

The Range of a shot or shell is the distance of its first graze upon a horizontal [illegible] the piece mounted upon its proper carriage.

[illegible]	Projectile. Description.	Projectile. Weight.	[illegible]	Initial Velocity.	Time of Flight.	Eleva-tion.	Range.
		Pounds.	Pounds.	Feet.	Seconds.	° ′	Yards.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Penetration of Shot and Shells.

[illegible]

:nts of Report of Board of Engineers for Fortifications, U. S. A. Professional Papers No. 25. (Brev. Maj.-Gen. Z. B. Tower.)

ɔerimental firings for penetration during the past twenty years have ɪined that wrought iron and cast iron, unless chilled, are unsuitable for tiles to be used against iron armor; that the best material for that ɜe is hammered steel or Whitworth's compressed steel.

'hat cast-iron and cast-steel armor-plates will break up under the im- ɪf the heaviest projectiles now in service, unless made so thick as to le their use in ship-protection.

'hat wrought-iron plates have been so perfected that they do not break t are penetrated by displacement or crowding aside of the material in .th of the shot, the rate of penetration bearing an approximately deter- . ratio to the striking energy of the projectile, measured per inch of circumference, as expressed by the following formula:

$$\sqrt[5]{\frac{V^2 P}{2\,g \times 2\,r\,\pi \times 2240 \times .86}} = \textit{penetration in ins.}$$ *V representing velocity in r second,* P *weight of shot in lbs., and r radius of shot in ins.*

ɪt such plates can therefore be safely used in ship construction, their ɪess being determined by the limit of flotation and the protection l.

:hat, though experiments with wrought-iron plates, faced with steel, not been sufficiently extended to determine the best combination of two materials, we may nevertheless assume that they give a resistance ·ut one fourth greater than those of homogenous iron.

:hat hammered steel in the late Spezzia trials proved superior to any material hitherto tested for armor-plates. The 19-inch plate resisted ·ation, and was only partially broken up by 4 shots, three of which had ɛing energy of between 33 000 and 34 000 foot-tons each. Not one shot ·ated the plate. Those of chilled iron were broken up, and the steel tile, though of excellent quality, was set up to about two thirds of its l.

ɜlocity and Ranges of Shot. (*Krupp's Ballistic Tables.*)

Penetration in Wrought Iron.

$$\sqrt{\frac{V^2 P}{2\,g \times 2\,r\,\pi \times 2240 \times C}} = \textit{penetration in ins.} \quad C = 2.53.$$

Gun.	Caliber.	Powder.	Shot.	Velocity at Muzzle per Sec.	Velocity Range. 3000	Velocity Range. 6000	Penetration at Muzzle	Penetration Range 600	Penetration Range 3000	Penetration Range 6000
Tons.	Ins.	Lbs.	Lbs.	Feet.	Yds.	Yds.	Ins.	Ins.	Ins.	Ins.
rong, 100..	17.75	550	2022	1715	1424	1191	34.76	33.2	27.55	22.04
" ..	17.75	776	2000	1832	1518	1259	37.52	35.81	29.66	23.47
'ich, 81..	16	445	1760	1657	1393	1181	32.6	31.23	26.24	21.35
71..	15.75	485	1715	1703	1434	1211	33.52	32.12	27.04	21.89
18..	9.45	165	474	1688	1351	1113	20.42	19.31	15.46	12.14
8-inch....	8	35	180	1450	1036	840	10.23	9.22	6.72	5.17

* Unchambered.

ɜt.—For 100-ton gun, steel plate 22 ins. thick, backed with 28.8 ins. of woo *ht-iron plates 1.5 ins. thick*, and the frame of a vessel.

—Total destruction of steel plate, and backing entered to a depth of 22 i *ɜrforated.*

Summary of Record of Practice in Europe with Heavy Armstrong, Woolwich, and Krupp Guns.

Board of Engineers for Fortifications, U. S. A., Professional Papers No. 25.

Gun.	Powder.	Projectile.	Charge of Powder.	Weight of Projectile.	Initial Velocity per Second. V.	Energy: Initial $\frac{PV^2}{2g \cdot 2240}$	Energy: per inch of circumference of shot.
			Lbs.	Lbs.	Feet.	Ft.-tons.	Foot-tons.
Armstrong, 100 Tons, caliber 17 ins., bore 30.5 feet.	1.5-inch cubes..	Shot....	330	2000	1446	28 990	544.45
	Waltham Abbey	"	375	2000	1543	33 000	623
	Fossano.......	"	400	2000	1502	31 282	585.74
	"	"	776	2000	1832	46 580	835.32
Woolwich, 81 Tons, caliber 14.5 ins., bore 24 feet.	.75-inch cubes.	"	170	1258	1393	16 922	371.5
	1.5 " "	"	220	1450	1440	20 842	457.57
	2 " "	"	250	1260	1523	20 259	444.78
caliber 16 ins.....	1.5 " "	"	310	1466	1553	24 508	520.4
38 Tons, caliber 12.5 ins., bore 16.5 feet.	1.5 " "	Pall. shell	130	800	1451	11 668	297.64
	1.5 " "	"	200	800	1421	11 210	285.4
	1.5 " "	"	180	800	1504	12 545	319.4
Krupp, 71 Tons, caliber 15.75 ins., bore 28.58 feet.	Prism A.......	Plain ...	298	1707	1184	16 602	335.42
	" H.......	Shrapnel	485	1725	1703	34 503	697.91
	" 2 inch...	Shell....	441	1419	1761	30 484	616.14
18 Tons, caliber 9.45 ins., bore 17.5 feet.	" 1 hole...	Plain ...	132	300	1873	7 298	246.03
	" 2 inch...	Shrapnel	145	474	1688	9 367	315.60
	"	Shell....	165	300	1991	8 244	277.69

Penetration in Ball Cartridge Paper, No. 1.

Musket, with 134 grains, at 13.3 yards.................... 653 sheets.
Common rifle, 92 grains, at 13.3 yards.................... 500 sheets.

Penetration of Lead Balls in Small Arms.

Experiments at Washington Arsenal in 1839, and at West Point in 1837.

Arm.	Diameter of Ball.	Charge Powder.	Distance.	Weight of Ball.	Penetration. White Oak.	Penetration. White Pine.
	Inch.	Grains.	Yards.	Grains.	Ins.	Ins.
Musket...............	.64	134	9	397.5	1.6	—
	.64	144	5	397.5	3	—
Common Rifle.........	—	100	5	219	2.05	—
	—	92	9	—	1.8	—
Hall's rifle............	—	100	5	219	2	—
	—	70	9	219	.6	—
...l's carbine, musket ...liber..............	.5775	70	5	—	1.7	—
		80	5	219	.8	—
		90*	5	—	1.1	—
		100*	5	—	1.2	—
...ol................	—	51	5	219	.725	—
...e musket..........	.5775	—	200	500	—	11
...ered musket.......	.685	60	200	730	—	10.5
Rifle, Harper's Ferry..	.5775	70	200	500	—	9.33
Pistol carbine.........	.5775	40	200	450	—	5.75
Sharpe's carbine......	.55	60	30	463	—	7.17
Burr	.55	55	30	350	—	6.15

* Charges too great for service.

...at 9 yards distance, with a charge of 134 grains, 1 ball ...ll a penetration of 1.15 ins., buckshot, .41 inch.

Loss cf Force by Windage.

nparison of results shows that 4 lbs. of powder give to a ball without wind- ırly as great a velocity as is given by 6 lbs. having .14 inch windage, which windage of a 24-lb. ball; or, in other words, this windage causes a loss of *one third* of force of charge.

'*s.*—Experiments show that loss of force by escape of gas from vent un is altogether inconsiderable when compared with whole force of
.

neter of *Vent* in U. S. Ordnance is in all cases .2 inch.

'ect of different Waddings with a Charge of 77 Grains of Powder.

WAD.	Velocity of Ball per Second.
	Feet.
wrapped in cartridge paper and crumpled..................	1377
; wad upon powder and 1 upon ball........................	1346
. wads upon powder and 1 upon ball.......................	1482
stic wad upon powder and 1 upon ball.....................	1132
iteboard wads upon powder................................	1200
stic wads upon powder....................................	1100

wads cut from body of a hat, weight 3 grains.

eboard wads .1 of an inch thick, weight 8 grains.

ridge paper 3 × 4.5 ins., weight 12.82 grains.

tic wads, "Baldwin's indented," a little more than .1 of an inch thick, , 5.127 grains.

it advantageous wads are those made of thick pasteboard, or of or- , cartridge paper.

ervice of *cannon*, heavy wads over ball are in all respects injurious.

purpose of retaining the ball in its place, light *grommets* should be used.

he other hand, it is of great importance, and especially so in use of small that there should be a good wad over powder for developing full force of ;, unless, as in the rifle, the ball has but very little windage. (*Capt. Mordecai.*)

Weight and Dimensions of Lead Balls.

Number of Balls in a Lb., from 1.67 to .237 of an Inch Diameter.

No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.	No.
	Inch.		Inch.		Inch.		Inch.		Inch.	
1	.75	11	.57	25	.388	80	.301	170	.259	270
2	.73	12	.537	30	.375	88	.295	180	.256	280
3	.71	13	.51	35	.372	90	.29	190	.252	290
4	.693	14	.505	36	.359	100	.285	200	.249	300
5	.677	15	.488	40	.348	110	.281	210	.247	310
6	.662	16	.469	45	.338	120	.276	220	.244	320
7	.65	17	.453	50	.329	130	.272	230	.242	330
8	.637	18	.426	60	.321	140	.268	240	.239	340
9	.625	19	.405	70	.314	150	.265	250	.237	350
10	.615	20	.395	75	.307	160	.262	260		

ted shot do not return to their original dimensions upon cooling, but retain ıanent enlargement of about .02 per cent. in volume.

Vumber of Pellets in an Ounce of Lead Shot of the different Sizes.

... 40 | B...... 75 | No. 3....... 135 | No. 6...... 280 | No. 9.....
.. 50 | No. 1...... 82 | 4....... 177 | 7...... 341 | 10.....
.. 58 | 2...... 112 | 5....... 218 | 8...... 600 | 12.....

No. 14............. 3150

Proportion of Powder to Shot for following Numbers of Shot.

No.	Shot.	Powder.	No.	Shot.	Powder.	No.	Shot.	Powder.
	Oz.	Drams.		Oz.	Drams.		Oz.	Drams.
2	2	1.5	4	1.5	1.875	6	1.25	2.375
3	1.75	1.625	5	1.375	2.125	7	1.125	2.625

NOTE.—2 oz. of No. 2 shot, with 1.5 drams of powder, produced greatest effect.

Increase of powder for greater number of pellets is in consequence of increased friction of their projection.

Numbers of Percussion Caps corresponding with Birmingham Numbers.

Eley's........	5	6	7	8	9	24	10	11	18	12	13	14
Birmingham..	43	44	46	48	49	50	51 and 52	53 and 54	55 and 56	57	[illegible]	[illegible]

Where there are two numbers of Birmingham sizes corresponding with only one of Eley's, it is in consequence of two numbers being of *same size*, varying only in length of caps.

Comparison of Force of a Charge in various Arms.

Arm.	Lock.	Powder, A 5.	Windage.	Weight of Ball.	Velocity.
		Grains.	Inch.	Grains.	Feet.
Ordinary rifle...........	Percussion.	100	.015	219	2018
" "	"	70	.015	219	1755
Hall's rifle...............	Flint.	70	.0	219	1490
Hall's carbine...........	Percussion.	70	.0	219	1340
Jenks's carbine.........	"	70	.0	219	1017
Cadet's musket.........	Flint.	70	.045	219	1690
Pistol..................	Percussion.	35	.015	218.5	917

Ranges for Small Arms.

Musket.—With a ball of 17 to pound, and a charge of 110 grains of powder, etc., an elevation of 36′ is required for a range of 200 yards; and for a range of 500 yards, an elevation of 3° 30′ is necessary, and at this distance a ball will pass through a pine board 1 inch in thickness.

Rifle.—With a charge of 70 grains, an effective range of from 300 to 350 yards is obtained; but as 75 grains can be used without *stripping* the ball, it is deemed better to use it, to allow for accidental loss, deterioration of powder, etc.

Pistol.—With a charge of 30 grains, the ball is projected through a pine board 1 inch in thickness at a distance of 80 yards.

Gunpowder.

Gunpowder is distinguished as *Musket*, *Mortar*, *Cannon*, *Mammoth*, and *Sporting* powder: it is all made in same manner, of same proportions of materials, and differs only in size of its grain.

Pressure or Explosive Energy.—By the experiments of Captain Rodman, U. S. Ordnance Corps, a pressure of 45 000 lbs. per square inch was obtained with 10 lbs. of powder, and a ball of 43 lbs.

Also, a pressure of 185 000 lbs. per sq. inch was obtained when the powder was burned in its own volume, in a cast-iron shell having diameters of 3.85 and 12 ins.

Proof of Powder. (*U. S. Ordnance Manual.*)

Powder in magazines that does not range over 150 yards is held to be unserviceable.

Good powder averages from 280 to 300 yards; small grain, from 300 to 320 yards.

Restoring Unserviceable Powder.—When powder has been damaged by being stored in damp places, it loses its strength, and requires to be worked over. If quantity of moisture absorbed does not exceed 7 per cent., it is sufficient to dry it to restore it for service. This is done by exposing it to the sun.

... has absorbed more than 7 per cent. of water it should be ... be worked over.

perties and Results of Gunpowder, determined by Experiments. (*Captain A. Mordecai, U. S. A.*)

24-POUNDER GUN.		MUSKET PENDULUM.	
ht of ball and wad....	24.25 lbs.	Weight of ball............	397.5 grains
" powder.........	6 "	" " powder.........	120 "
age of ball...........	.135 inch.	Windage of ball...........	.09 inch

GRAIN.	Composition. Salt-petre.	Char-coal.	Sul-phur.	Manufacture. Where from.	Number of Grains in 10 Troy Grains.	Relative Quickness of Burning.	Water absorbed by exposure to Air.	Relative Force.
							Per c't.	
on, large...					77	275	2.77	.677
small...					569	314	3.35	.72
et.........					1 134	214	—	.808
....	76	14	12	* Dupont's Mills,	6 174	142	—	.907
....				Del.	5 344	282	3.55	.728
et.........					1 642	—	—	.834
....					13 152	—	—	.943
on, uneven.				† Dupont's Mills,	166	183	2.09	.788
large...	75	12.5	12.5	Del.	103	182	1.91	.756
ing.........	77	13	10	* Dupont's Mills,	72 808	100	4.42	1
ing, uneven	70	15	15	Del.	295	212	—	—
....				Loomis, Hazard,	2 378	204	—	.82
ing.........	76	15	9	& Co., Conn.*	—	—	—	.888
....	75	15	10	Waltham Abbey, England.*	11 600	—	—	.865

* Glazed. † Rough.

nufacture of Powder.—Powder of greatest force, whether for cannon or small is produced by incorporation in the "cylinder mills."

ect of Size of Grain.—Within limits of difference in size of grain, which occurs linary cannon powder, the granulation appears to exercise but little influence force of it, unless grain be exceedingly dense and hard.

ect of Glazing.—Glazing is favorable to production of greatest force, and to combustion of grains, by affording a rapid transmission of flame through of the powder.

ect of using Percussion Primers.—Increase of force by use of primers, *which y closes vent*, is constant and appreciable in amount, yet not of sufficient value thorize a reduction of charge.

*o of Relative Strength of different Powders for use under water differ t little from the reciprocal of the ratio between the sizes of the grains, owing that the strength is nearly inversely proportional thereto.**

ammoth, .08; Oliver, .09; Cannon, .18; Mortar, 1; Musket, 1.57; ·ting 2.61, and Safety Compound 30.62.

ualin is nitro-glycerine absorbed by Schultze's powder.

r other powders and explosive materials see Blasting, p. 443.

Heat and Explosive Power. (*Capt. Noble and F. A. Abel.*)

ne gram of fired powder evolves a mean temperature of 730°. Temper- e of explosion 3970°. Volume of permanent gas (which is in an in- e ratio to units of heat evolved) at 32° = 250.

he explosive power of powder, as tested in Ordnance, ranges, for volumes xpansion of 1.5 to 50 times, from 36 to 170 *foot-tons* per lb. burned.

charge *of 70 lbs. gave to an* 180 lbs. shot a velocity of 1694 feet per *nd, equal to a total energy of* 3637 *foot-tons*, and a charge of 100 lbs a *velocity of 2182 feet*, and an energy of 5940 *foot-tons*.

* *rt of Experiments and Investigations to develop a system of submarine mines.* Profess. *S. E., No. 23.*

HEAT.

Heat, alike to gravity, is a universal force, and is referred to both as cause and effect.

Caloric is usually treated of as a material substance, though its claims to this distinction are not decided; the strongest argument in favor of this position is that of its power of radiation. Upon touching a body having a higher temperature than our own, caloric passes from it, and excites the feeling of warmth; and when we touch a body having a lower temperature than our own, caloric passes from our body to it, and thus arises the sensation of cold.

To avoid any ambiguity that may arise from use of the same expression, it is usual and proper to employ the word *Caloric* to signify the principle or cause of sensation of heat.

Heat Unit.—For purpose of expressing and comparing quantities of heat, it is convenient and customary to adopt a *Unit of heat* or *Thermal unit*, being that quantity of heat which is raised or lost in a defined period of temperature in a defined weight of a particular substance.

Thus, a Thermal unit, *Is quantity of heat which corresponds to an interval of 1° in temperature of 1 lb. of pure liquid water, at and near its temperature of greatest density.*

Thermal unit in France, termed *Caloric*, *Is quantity of heat which corresponds to an interval of 1° C. in temperature of 1 kilogramme of pure liquid water, at and near its temperature of greatest density.*

Thermal unit to Caloric, 3.968 32; Caloric to Thermal unit, .251 996.

One Thermal unit or 1° in 1 lb. of water, 772 foot-lbs.
One Caloric or 1° C. in 1 kilogramme of water, 423.55 kilogrammetres.
1° C. in 1 lb. water, 1389.6 foot-lbs.

Ratio of Fahrenheit to Centigrade, 1.8; of Centigrade to Fahrenheit, .555.

Absolute Temperature, Is a temperature assigned by deduction, as an opportunity of observing it cannot occur, it being the temperature corresponding to entire absence of gaseous elasticity, or when pressure and volume = 0. By Fahrenheit it is—461.2°, by Reaumur—229.2°, and by Centigrade—274°.

Heat is termed *Sensible* when it diffuses itself to all surrounding bodies; hence it is free and uncombined, passing from one substance to another, affecting the senses in its passage, determining the height of the thermometer, etc.

Temperature of a body, is the quantity of sensible heat in it, present at any moment.

Heat is developed by water when it is violently agitated.

Heat is developed by percussion of a metal, and it is greatest at the first blow.

Quantities of heat evolved are nearly the same for same substance, without reference to temperat... ...its combustion.

Mechanical power m... ...ed in production of heat either by fric*tion or compression*, ... heat produced bears the same propor*tion to quantity of* ... ...r expended, being 1 unit for power necessary to raise 1 ... This number of 772 is termed *the mechanical equi*...

Specific Heat.

pecific Heat of a body signifies its capacity for heat, or quantity re-
:ed to raise temperature of a body 1°, or it is that which is ab-
)ed by different bodies of equal weights or volumes when their
perature is equal, based upon the law, *That similar quantities of*
erent bodies require unequal quantities of heat at any given tempera-
:. It is also the *quantity of heat* requisite to change the tempera-
; of a body any stated number of degrees compared with that which
ıld produce same effect upon water at 32°.

uantity of heat, therefore, is the quantity necessary to change the tem-
ıture of a body by any given amount (as 1°), divided by quantity of
t necessary to change an equal weight or volume of water 32° by same
)unt.

OTE.—Water has greater specific heat than any known body.

;very substance has a specific heat peculiar to itself, whence a change of
ıposition will be attended by a change of its capacity for heat.

pecific heat of a body varies with its form. A solid has a less capacity
heat than same substance when in state of a liquid; specific heat of
.er, for instance, being .5 in solid state (ice), .622 in gaseous (steam),
. 1 in liquid.

pecific heat of equal weights of same gas increases as density decreases;
.ct rate of increase is not known, but ratio is less rapid than diminution
lensity.

;hange of capacity for heat always occasions a change of temperature.
rease in former is attended by diminution of latter, and contrariwise.

Specific heat multiplied by atomic weight of a substance will give
constant 37.5 as an average, which shows that the atoms of all
›stances have equal capacity for heat. This is a result for which as
no reason has been assigned.

hus: atomic weights of lead and copper are respectively 1294.5 and 395.7, and
ir specific heats are .031 and .095. Hence 1294.5 × .031 = 40.129, and 395.7 ×
; = 37.591.

t is important to know the relative Specific Heat of bodies. The most conve-
nt method of discovering it is by mixing different substances together at dif-
›nt temperatures, and noting temperature of mixture; and by experiments it
›ears that the same quantity of heat imparts twice as high a temperature to
rcury as to an equal quantity of water; thus, when water at 100° and mercury
40° are mixed together, the mixture will be at 80°, the 20° lost by the water
sing a rise of 40° in the mercury; and when weights are substituted for meas-
s, the fact is strikingly illustrated; for instance, on mixing a pound of mercury
40° with a pound of water at 160°, a thermometer placed in it will fall to 155°.
ıs it appears that same quantity of heat imparts twice as high a temperature to
rcury as to an equal volume of water, and that the heat which gives 5° to water
l raise an equal weight of mercury 115°, being the ratio of 1 to 23. Hence, if
ıal quantities of heat be added to equal weights of water and mercury, their
ıperatures will be expressed in relation to each other by numbers 1 and 23; or,
order to increase the temperature of equal weights of th ... es to the
ıe extent, the water will require 23 times as much heat as

Capacity for Heat is relative power of a body in ... re-
ning heat in being raised to any given temperat...
plies to actual quantity of heat so received and re.

Specific Heat of Air and other ...

ecific heat, or capacity for heat, of permanent gases i...
ll temperatures, and for all densities. Capacity for h...

same for each degree of temperature. M. Regnault proved th for heat for air was uniform for temperatures varying fron $+437^\circ$; consequently, specific heat for equal weights of air, a pressure, averaged .2377.

Specific Heat. *Water at* $32^\circ = 1$.

Metals from 32° *to* 212°.				*Woods.*		Sulphu
Antimony	.0508	Silver	.056	Oak	.57	*L*
Bismuth	.0308	Steel	.1165	Pear	.5	Alcohol
Brass	.0939	Tin	.0562	Pine	.65	Ether ..
Copper	.092	Wrought iron	.1138	*Min'l Substances.*		Linseed
Cast iron	.1298	Zinc	.0955	Charcoal	.2415	Olive oi
Gold	.0324	*Stones.*		Coal	.2411	Steam.
Lead	.0314	Chalk	.2149	Coke	.203	Turpen
Mercury	.0333	Limestone	.2174	Glass	.1977	Vinegai
Nickel	.1086	Masonry	.2	Gypsum	.1966	
Platinum	.0324	Marble, gray	.2694	Phosphorus	.2503	
		" white	.2158			Ice....

Gases.

Air	.2377	Hydrogen	
Oxygen	.2412	Carbonic Acid	

For Equal Weights.

Air	.1688	Hydrogen	
Oxygen	.1559	Carbonic Acid	

Metals have least, ranging from Bismuth .0308 to Cast Iron .1298. Mineral Substances have .2 that of water, and Woods about .5. Liqui ception of Bromine, are less than water, Olive oil being lowest and Vine

ILLUSTRATION.—If 1 lb. of coal will heat 1 lb. of water to 100°, $\frac{1}{.033}$ heat 1 lb. of mercury to 100°.

To Compute Temperature of a Mixture of lil stances.

$\frac{W\,T + w\,t}{W + w} = t'$; $\quad \frac{w\,(t' - t)}{T - t'} = W$; $\quad \frac{w\,(t' - t)}{W} + t' = T$. W *represen or volume of a substance of temperature* T, *w weight or volume of a like temperature t, and t' temperature of mixture* $W + w$.

ILLUSTRATION 1.—When 5 cube feet of water (W) at a temperature o mixed with 7.5 cube feet (w) at 50° (t), what is the resultant tempera mixture?

$$\frac{5 \times 150^\circ + 7.5 \times 50^\circ}{5 + 7.5} = \frac{1125}{12.5} = 90^\circ.$$

2.—How much water at (T) 100° should be mixed with 30 gallons (w a required temperature of 80°?

$$\frac{30\,(80^\circ - 60^\circ)}{100^\circ - 80^\circ} = \frac{600}{20} = 30 \textit{ gallons.}$$

To Compute Temperature of a Mixture of I Substances.

$\frac{W\,S\,T + w\,s\,t}{W\,S + w\,s} = t'$; $\quad \frac{w\,s\,(t - t')}{S\,(T - t)} = W$; $\quad \frac{t'\,(W\,S + w\,s) \sim w\,s\,t}{W\,S} = T$.

nting weights, and S *and s specific heat of substances.*

hat temperature should 20 lbs. cast iron (W) to a temperature (t) of 50° to 60°?

$$\frac{o \times .1298 + 150 \times 1) \sim 150 \times 1 \times 50^\circ}{20 \times .1298} =$$

To Compute Specific Heat at Constant Volume.

When Specific Heat at Constant Pressure is known. $\frac{S\,p}{H} = s$. S *representing specific heat at constant pressure,* p *proportion of heat absorbed at constant volume,* H *total heat absorbed at constant pressure, and* s *specific heat at constant volume.*

Or, $\frac{S\,(t'-t) - 2.742\,(V-v)}{t'-t} = s$. *t and t′ representing initial and final temperature of the gas and that to which it is raised, and* V *and* v *initial and final volumes of the gas under 14.7 lbs. per sq. inch, and of it heated under constant pressure in cube feet.*

ILLUSTRATION.—Assume 1 lb. air at atmospheric pressure and at 32°, doubled in volume by heat. $S = .2377$*, $t - t' = 32° \sim 525° = 493°$ and $V - v = 12.387$* *cube feet.*

$$\frac{.2377 \times 493 - (2.742 \times 12.387)}{493} = .1688 \text{ specific heat.}$$

For comparative volumes of other gases, see Table, page 506.

To Compute Specific Heat for Equal Volume of Gas and Air.

RULE.—Multiply specific heat of the gas for equal weights of gas and air by specific gravity of gas, and product is specific heat for equal volume.

EXAMPLE.—What is specific heat of air at equal volume with hydrogen?

Specific heat of hydrogen for equal weights at constant volume, 2.4096, and specific gravity of the gas, .0692. (See Table, page 506.)

Then, $2.4096 \times .0692 = .1667$ *specific heat for equal volumes at constant volume.*

Specific heat of steam, air at unity = 1.281.

Capacity for Heat.

When a body has its density increased, its capacity for heat is diminished. The rapid reduction of air to .2 of its volume evolves heat sufficient to inflame tinder, which requires 550°.

Relative Capacity for Heat of Various Bodies. (*Water at* 32° = 1.)

Bodies.	Equal Weights.	Equal Volumes.	Bodies.	Equal Weights.	Equal Volumes.	Bodies.	Equal Weights.	Equal Volumes.
Water..	1	1	Gold....	.05	.966	Mercury	.036	—
Brass...	.116	.971	Ice.....	.9	—	Silver..	.082	.833
Copper..	.114	1.027	Iron....	.126	.993	Tin.....	.06	—
Glass...	.187	.448	Lead...	.043	.487	Zinc....	.102	—

To Ascertain Relative Capacities of Different Bodies, combined with experiment.

RULE.—Multiply weight of each body by number of degrees of heat lost or gained by mixture, and capacities of bodies will be inversely as products.

Or, if bodies be mingled in unequal quantities, capacities of the bodies will be reciprocally as quantities of matter, multiplied into their respective changes of temperature.

ILLUSTRATION.—If 1 lb. of water at 156° is mixed with 1 lb. of mercury at 40°, resultant temperature is 152°.

Thus, $1 \times 156° - 152° = 4°$, and $1 \times 40° \sim 152° = 112°$. Hence capacity of water for heat is to capacity of mercury as 112° to 4°, or [illegible]

Sensible He[illegible]

Sensible heat or temperature to raise wate[illegible] [illegible]° = 180.9[illegible] *units.*

* See Tables, pages 506 an[illegible]

Latent Heat.

Latent Heat **is that which is insensible to the touch of our b**
and is incapable of being detected by a thermometer.

When a solid body is exposed to heat, and ultimately passes int liquid state under its influence, its temperature rises until it attain point of fusion, or melting point. The temperature of the body a point remains stationary until the whole of it is melted; and the heat i time absorbed, without affecting the temperature or being sensible t touch or to the indications of a thermometer, is said to become *latent.* in fact, *the latent heat of fusion*, or *the latent heat of liquidity*, and its tion is to separate the particles of the body, hitherto solid, and change condition into that of a liquid. When, on the contrary, a liquid is soli the latent heat is disengaged.

If to a pound of newly-fallen snow were added a pound of water at the snow would be melted, and 32° would be resulting temperature.

When a body is *fusing*, no rise in its temperature occurs, however the additional quantity of heat may be imparted to it, as the increased is absorbed in the operation of fusion. The quantity of heat thus latent varies in different bodies.

A pound of water, in passing from a liquid at 212° to steam at 212 ceives as much heat as would be sufficient to raise it through 966.6 mometric degrees, if that heat, instead of becoming *latent*, had been se

If 5.5 lbs. of water, at temperature of 32°, be placed in a vessel, communi with another one (in which water is kept constantly boiling at temperature of until former reaches temperature of latter quantity, then let it be weighe it will be found to weigh 6.5 lbs., showing that one lb. of water has been re in form of steam through communication, and reconverted into water by temperature in vessel. Now this pound of water, received in the form of s had, when in that form, a temperature of 212°. It is now converted into form, and still retains same temperature of 212°; but it has caused 5.5 lbs. of to rise from the temperature of 32° to 212°, and this without losing any ten ture of itself. Now this heat was combined with the steam, but as it is not se to a thermometer, it is termed *Latent.*

Quantity of heat necessary to enable ice to resume the fluid state is to that which would raise temperature of same weight of water 140°; a equal quantity of heat is set free from water when it assumes the solid:

Sum of Sensible and Latent Heats.

From Water at 32°.

Pressure.	Latent.	Sum.	Pressure.	Latent.	Sum.	Pressure.	Latent.	Sum.	Pressure.	Latent.
Lbs.	°	°	Lbs.	°	°	Lbs.	°	°	Lbs.	°
14.7	964.3	1146.1	26	943.7	1155.3	55	912	1169	120	873.7
16	962.1	1147.4	27	942.2	1155.8	60	908	1170.7	130	869.4
17	959.8	1148.3	28	940.8	1156.4	65	904.2	1172.3	140	865.4
18	957.7	1149.2	29	939.4	1157.1	70	900.8	1173.8	150	861.5
19	955.7	1150.1	30	937.9	1157.8	75	897.5	1175.2	160	857.9
20	952.8	1150.9	32	935.3	1158.9	80	894.3	1176.5	170	854.5
21	951.3	1151.7	35	931.6	1160.5	85	891.4	1177.9	180	851.3
22	949.9	1152.5	37	929.3	1161.5	90	888.5	1179.1	190	848
23	948.5	1153.2	40	926	1162.9	95	885.8	1180.3	200	845
24	946.9	1153.9	45	920.9	1164.6	100	883.1	1181.4	220	829.2
25	945.3	1154.6	50	916.3	1167.1	110	878.3	1183.5	250	831.2

Latent Heat of Vaporization, or Number of Degrees of *Heat required to* ...nces *from their* Liquidities to Vapor at Pr

.... 142.6° \ Water..........
.... 157° \ Zinc..........
...... 298° \ Oil of Turpenti

Latent Heat of Fusion of Solids. (*Person.*)

Substances.	Melting Point.	Specific Heat. Liquid.	Specific Heat. Solid.	In Heat-units of 1 lb.	Substances.	Melting Point.	Specific Heat. Liquid.	Specific Heat. Solid.	In Heat units of 1 lb.
	°	°	°			c	°	°	
Tin	442	.0637	.0562	25.6	Ice	32	1	.504	142.85
Bismuth	507	.0363	.0308	22.7	Phosphorus	112	.2045	.1788	9
Lead	617	.0402	.0314	9.86	Spermaceti	120	—		148
Zinc	773	—	.0956	50.6	Wax	142	—		175
Silver	1873	—	.057	37.9	Sulphur	239	.234	.2026	17
Mercury	39	.0333	.0319	5	Nitrate of soda	591	.413	.2782	113
Cast iron	3400	—	.129	233	Nit. of potassia	642	.3319	.2388	85

To Compute Latent Heat of Fusion of a Non-metallic Substance.

$C \backsim c\,(t + 256°) = L$. *C and c representing specific heats of substance in solid and liquid state, t temperature of fusion, and L latent heat.*

ILLUSTRATION.—What is latent heat of fusion of ice?

$C = .504$; $c = 1$; and $t = 32°$.

$$.504 \backsim 1 \times \overline{32 + 256} = 142.85° \text{ units.}$$

NOTE.—For Latent Heat of Fusion of some substances, see Deschanel's, New York 1872, Heat, part 2.

Radiation of Heat.

Radiation of Heat is diffusion of heat by projection of it in diverging right lines into space, from a body having a higher temperature than space surrounding it, or body or bodies enveloping it.

Radiation is affected by nature of surface of body; thus, black and rough surfaces radiate and absorb more heat than light and polished surfaces. Bodies which radiate heat best absorb it best.

Radiant heat passes through moderate thicknesses of air and gas without suffering any appreciable loss or heating them. When a polished surface receives a ray of heat, it absorbs a portion of it and reflects the rest. The quantity of heat absorbed by the body from its surface is the measure of its *absorbing power*, and the heat reflected, that of its *reflecting power*.

When temperature of a body remains constant it is in consequence of quantity of heat emitted being equal to quantity of heat absorbed by body. Reflecting power of a body is complement of its absorbing power; or, sum of absorbing and reflecting powers of all bodies is the same.

Thus, if quantity of heat which strikes a body = 100, and radiating and reflecting powers each 90, the absorbent would be 10.

Radiating or Absorbent and Reflecting Powers of Substances.

SUBSTANCES.	Radiating or Absorbing.	Reflecting.	SUBSTANCES.	Radiating or Absorbing.	Reflecting.
Lamp Black	100	—	Wrought Iron, polished	23	77
Water	100	—	Lead, polished	19	81
Carbonate of Lead	100	—	Zinc, polished	19	81
Lead, white	100	—	Steel, polished	17	83
Writing Paper	98	2	Platinum, in sheet	17	83
Ivory, Jet, Marble	93 to 98	7 to 2	Tin	15	85
Resin	96	4	Copper, varnished	14	86
Glass	90	10	Brass, dead polished	11	89
India Ink	85	15	" bright polished	—	93
Ice	85	15	Copper, ham'ered or		
Shellac	72	28	" deposited on		
Lead	45	55	Gold, plated		
Cast Iron, bright polished	25	75	" polished		
Platinum, a little polish'd	24	76	Silver, polished		
Mercury	23	77	" cast, polish		

Radiating and Absorbing Power of various Bodie[s] Units of Heat per Sq. Foot per Hour for a Differ[ence] of 1°. (*Peclet.*)

	Unit.		Unit.		
Silver, polished	.0266	Iron, ordinary	.5662	Woollen stuff	
Copper	.0327	Glass	.5948	Oil paint	
Tin	.0439	Iron, cast	.648	Paper	
Brass, polished	.0491	Wood sawdust	.7225	Lamp-black	
Iron, sheet	.092	Stone, Brick, etc.	.7358	Water	

To Compute Loss of Heat by Radiation per Sq. I[...]

$\frac{1.7\,l\,(T-t)}{d\,v}=R.$ *T representing temperature of pipe, which is assumed to [...] less than that of steam; t temperature of air; l length of pipe, and v velocity in feet per second; d diameter in ins., and R radiation in degrees per second.*

ILLUSTRATION.—Assume temperatures of a steam-pipe, steam, 212°, 200°, [...] 60°, length of pipe 20 feet, velocity of heat (steam) 15 feet per second, and d[...] of pipe 16 ins.; what will be loss of heat by radiation?

$$\frac{1.7\times 20\,(200-60)}{16\times 15}=15.66°.$$

Reflection.

Reflection of Heat is passage of heat from surface of one sub[...] to another or into space, and it is the converse of radiation.

Heat is reflected from surface upon which its rays fall in same ma[...] light, angle of reflection being opposite and equal to that of incidence. [...] als are the strongest reflectors.

Reflecting Power of various Substances.

Silver	.97	Specular metal	.86	Zinc	
Gold	.95	Tin	.85	Iron	
Brass	.93	Steel	.83	Lead	

Communication and Transmission of Heat.

Communication of Heat is passage of heat through different [...] with different degrees of velocity. This has led to division of [...] into *Conductors* and *Non-conductors;* former includes such as [...] which allow caloric to pass freely through their substance, and [...] comprise those that do not give an easy passage to it, such as [...] glass, wood, charcoal, etc.

Velocity of cooling, other things being equal, increases with extent [...] face compared with volume of substance; and of two bodies of same [...] rial, temperature, and form, but differing in volume.

Transmission of Heat is passage of heat through different bodies wi[...] ferent degrees of intensity. Gaseous bodies and a vacuum are hig[...] order of transmittents.

Relative Power of various Substances to Transmit Heat.

All bodies capable of transmitting heat are more or less trans[...] though their powers of transmitting heat and light are not in sam[...] tive proportions.

Air	1	Flint-glass	.67	Nitric acid	.15	Sulphuric a[...]	
Alcohol	.15	Gypsum	.2	Rock-crystal	.62	Turpentine	
Crown-glass	.49	Ice	.06	Rape-seed oil	.3	Water	

Heat which passes through one plate of glass is less subject to abs[...] in passing through a second and a third plate. Of 1000 rays, 451 w[...] tercepted by 4 plates as follows:

1st. 381. 2d. 43. 3d. 18. 4th. 9.

erage Results of Heating and Evaporating Water by Steam in Copper Pipes and Boilers. (*D. K. Clark.*)

	Steam condensed Per sq. foot for 1° difference per hour. Heating.	Evaporating.	Heat transmitted Heating.	Evaporating
	Lbs.	Lbs.	Units.	Units.
iron plate surface	.077	.105	82	100
er-plate surface	.248	.483	276	534
er-pipe surface	.291	1.07	312	1034

hence.—Efficiency of copper-plate surface for evaporation of water is le its efficiency for heating; for copper-pipe surface efficiency is more three times as much; and for cast-iron-plate surface, a fourth more. ficiency of pipe surface is a fifth more than that of plate surface for ing, and more than twice as much for evaporation.

nerally, copper-plate surface condenses .5 lb. of steam, copper-pipe , and cast-iron-plate surface .1 lb. per sq. foot per 1° of temperature per , for evaporation.

antity of heat transmitted is at rate of about 1000 units per lb. of steam ensed.

Transmission of Heat through Glass of different Colors.

Direct = 100.

	65.5	Blue, deep	19	Yellow	40
low	52	" light	42	Orange	44
t, deep	53	Green	26	Red	53

. Peclet defines law of transmission of heat as: The flow of heat which rses an element of a body in a unit of time is proportional to its sur- and to difference of temperature of the two faces perpendicular to direc- of flow, and is in inverse of thickness of element.

$(t - t')\frac{C}{T} = H.$ *t and t′ representing temperatures of surfaces,* C *constant for rial 1 inch thick, or quantity of heat transmitted per hour for 1° difference of rature through 1 unit of thickness,* T *thickness, and* H *quantity of heat in units d through plate per sq. foot per hour.*

antities of Heat transmitted from Water to Water hrough Plates or Beds of Metals and other Solid Bodies, 1 Inch thick, per Sq. Foot.

For 1° Difference of Temperature between the two Faces per Hour.

Selected from M. Peclet's tables. (*D. K. Clark.*)

ubstance.	C or Quantity of Heat.	Substance.	C or Quantity of Heat.	Substance.	C or Quantity of Heat.
	Units.		Units.		Units.
	620	Iron	225	Marble	24
num	604	Zinc	225	Plaster	2.6
r	596	Tin	177	Glass	6.56
er	555	Lead	112	Sand	2.16

e conditions are, that the surfaces of conducting material must be per- y clean, that they be in contact with water at both faces of different eratures, and that the water in contact with surfaces be thoroughly and tantly changed. M. Peclet found that when metallic surfaces became rate of transmission of heat through all metals became very nearly ame.

To Compute Units of Heat Transm

ustration I. —*If 2000 lbs.* beet root juice at 40° are con *with a double bottom,* and heated to 212°, with a heating s *bjected to steam at a temperature of* 275°, for a period *the total heat, and* heat per degree of difference transmit

$212^\circ - 40^\circ \times 60 \div 15 = 688^\circ$ *per hour*, and $2000 \times 688 \div 25 = 55\,040$ *un*
foot per hour.

$(212^\circ + 40^\circ) \div 2 = 126^\circ$ *mean temperature of juice*, and $275^\circ - 126^\circ =$
difference of temperature.

Hence, $55\,040 \div 149 = 369.4$ *units per sq. foot per degree of difference pe*

2.—If 48.2 sq. feet of iron pipe 1.36 ins. in diameter, is supplied with stea and it raises temperature of 882 lbs. water from 46° to 212° in 4 minutes, be total heat per sq. foot per hour, total heat per sq. foot per degree, an condensed per sq. foot per degree per hour?

$212^\circ - 46^\circ \times 60 \div 4 = 2490^\circ$ *in an hour*; $46^\circ + 212^\circ \div 2 = 129^\circ$ *mea ature*, and $275^\circ - 129^\circ = 146^\circ$ *difference of temperature.*

$\frac{2490^\circ \times 882}{48.2} = 45\,563$ *units per sq. foot per hour*, $45\,563 \div 146 = 312.1$ *un*
foot per degree, and total heat of steam above $129^\circ = 1068^\circ$.

Hence $\frac{312.1}{1068} = .292$ *lbs. steam condensed per sq. foot per degree per hour.*

Evaporation.

Evaporation or *Vaporization* is conversion of a fluid into v it produces cold in consequence of heat being absorbed to for

It proceeds only from surface of fluids, and therefore, *other thi* must depend upon extent of surface exposed.

When a liquid is covered by a stratum of dry air, evaporation even when temperature is low.

As a large quantity of heat passes from a sensible to a latent sta formation of vapor, it follows that cold is generated by evaporatio

Fluids evaporate in vacuo at from 120° to 125° below their boil

Heat required to Evaporate 1 lb. Water at Tempe below 212° from a Vessel in open air at 32

(*Thomas Box.*)

Temperature.	Water evapor'd per sq. foot of surface p'r hour.	HEAT lost by radiation from surface.	HEAT lost in air.	HEAT to evaporate 1 lb. of water.	HEAT Total lost per hour.	Temperature.	Water evapor'd per sq. foot of surface p'r hour.	HEAT lost by radiation from surface.	HEAT lost in air.
°	Lbs.	Units.	Units.	Units.	Units.	°	Lbs.	Units.	Units.
32	.027	—	—	1091	29	132	.706	182	202
42	.04	270	424	1788	71	142	.916	158	162
52	.058	375	581	2052	119	152	1.178	137	127
62	.083	405	605	2110	174	162	1.505	118	97
72	.117	386	566	2055	239	172	1.895	106	72
82	.162	358	504	1968	319	182	2.373	92	50
92	.223	319	434	1862	415	192	2.947	81	32
102	.303	280	366	1758	533	202	3.633	71	14
112	.406	245	304	1664	671	212	4.471	63	—
122	.528	211	250	1580	849	—	—	—	—

To Compute Surface of a Refrigerator.

Illustration of Table.—If it is required to cool 20 barrels, of 42 gallon beer, from 202° to 82° in an hour.

Result to be attained is to dissipate 42×8.33 (lbs. U. S. gallons) $\times 20$ $= 840\,000$ *units of heat per hour.*

At 202°, 4465 units are lost, and at 82°, 319, hence, average loss for eac ature between extremes = 1850 units per sq. foot per *hour.*

Then $\frac{840\,000}{1850} = 454$ sq. feet in a still air.

The volume of air required per hour in this case would be about 10

mpute Area of Grate and Consumption of Fuel for Evaporation.

tion of Table.—If it is required to evaporate 6 Beer gallons ... per hour, at a temperature not exceeding 152°.

s = 50 lbs. At 152°, water evaporated as per table ... 1.17 ...

42 *sq. feet.* Heat required to effect this = 1392 × ...

ng 6000 units as average economic value of coals, then ...

grate of 1 sq. foot.

: is practicable to evaporate at a high temperature ... economical.

ater requires only 1209 units per lb. if surface ... duced (1209 — 63) to 1146 units.

tive Powers of Different Tubes per Degree of Heat ... Surface.—In Units.

l tube, 230; Double-bottomed vessel, 330; ...

mpute Volume of Water Evaporated ... Time.

LATION.—What is volume evaporated at ... n a double-bottomed vessel having an area of ... cted to steam at a pressure of 25 lbs.?

rature of steam at 25 + 14.7 lbs. ... 17.

$$\text{Then } \frac{330 \times 57 \times 17 \times 15}{927 \times 60} \ldots$$

When Water is at a Lower Temperature than ...

› gallons or 1000 lbs. of water were to be ... m same vessel and under like ...

would be required 1000 × (212° — ...

rater while being heated = ...

nce between temperature of ...

$$\frac{170000}{330 \times 140 \times 17} = .216 \textit{ hour} = \ldots$$

r left for evaporation, and ...

:, or 32.44 *gallons.*

D...

iccation, or the drying of ... r, and it is imperative ... be admitted at highest ... l at its lowest.

l, submitted *to an average* ... *riod of 2.5 days, will* ... *r 10.5 lbs. of wood* ... *of water per lb. of* ...

f temperature ...

Evaporation of Water per Sq. Foot of Surface per Ho

(*Dr. Dalton.*)

Temperature of Water.	Evaporation. Calm.	Light Air.	Brisk Wind.	Temperature of Water.	Evaporation. Calm.	Light Air.	B W
°	Lbs.	Lbs.	Lbs.	°	Lbs.	Lbs.	
32	.0349	.0448	.055	100	.3248	.4169	
40	.0459	.0589	.0723	125	.6619	.8494	
50	.0655	.0841	.1032	150	1.296	1.663	
60	.0917	.1175	.1441	175	2.378	3.053	
70	.1257	.1616	.1983	200	4.128	5.298	
80	.1746	.2241	.2751	212	5.239	6.724	

The rates of evaporation for these conditions of the air when perfectly dry 1, 1.28, and 1.57.

To Compute Quantity of Water exposed to Air that would be evaporat above.—Subtract tabulated weight of water corresponding to dew-point weight of water corresponding to temperature of dry air, and remain weight of water that would be evaporated per sq. foot of surface per h

Distillation.

Distillation is depriving vapor of its latent heat, and, though it be effected in a vacuum with very little heat, no advantage in rega a saving of fuel is gained, as latent heat of vapor is increased pr tionately to diminution of sensible heat.

A temperature of 70° is sufficient for distillation of water in a vess hausted of air.

Conduction or Convection of Heat.

Air and gases are very imperfect conductors. Heat appears transmitted through them almost entirely by conveyance, the h portions of air becoming lighter, and diffusing the heat throug mass in their ascent. Hence, in heating a room with air, the h should be introduced at lowest part. The advantage of double dows for retention of heat depends, in a great measure, upon sheet confined between them, through which heat is very slowly transmi

Convection of heat refers to transfer and diffusion of heat in a fluid by means of the motion of the particles of the mass.

Relative Internal Conducting Powers of Variou Substances.

Metals.

Brass	.76	Gold	1	Porcelain	.012	Tin	
Cast Iron	.517	Lead	.18	Silver	.97	Wrought Iron	
Copper	.89	Platinum	.98	Terra Cotta	.011	Zinc	

Minerals.

Cement	.21	Coal, anth'cite	1.92	Fire brick	.61	Gypsum	
Chalk	.6	" bitumin.	1.68	Fire clay	.76	Lime	
Charcoal	.07	Coke	1.98	Glass	.96	Marble	
Slate	1			Wood ash	.08		

Woods with Birch = .41 with Silver.

Apple	.68	Birch	1	Ebony	.5	Oak	
Ash	.73	Chestnut	.7	Elm	.73	Pine	

Hair and Fur with Air = 1.

Cotton	.55	Flannel	2.44	Hair	2	Silk	
Elder down	.44	Hemp Canvas	.28	Hare's fur	.43	Wool	

Liquids with Water.

Alcohol	.93	Proof spirit	.85	Turpentine	
Mercury	2.8	Sulphuric acid	1.7	Water	

Practical Deductions from preceding Results.

Asphalt is best composition for resisting moisture, and, being a slow conluctor of heat, it is best adapted for economy of heat and dryness.

Slate is a very dry material, but, from its quick conducting power, it is lot adapted for retention of heat.

Cements.* — *Plaster of Paris and Woods are well adapted for lining of ooms, having low conductive powers, while *Hair and Lime*, being a quick onductor, is one of the coldest compositions.

Fire-brick absorbs much heat, and is well adapted for lining of fire-places, tc.; while *Iron*, being a high conductor of heat, is one of the worst of subtances for this purpose. ***Common brick*** is not a very slow conductor of heat.

Steam Pipe.—A wrought-iron pipe, 4 ins. in internal diameter, conveying team at a pressure of 35 lbs. per sq. inch (280°) and 100 feet in length, vill lose .84 IP.

Casing to Pipes.—A like pipe with the above, cased with following mateials and covered with canvas, to give like radiating power to the outer urface, gave loss of heat in units per hour, and for the thickness given, as ollows:

Casing.	.5 Inch.	1 Inch.	2 Inches.	4 Inches.	6 Inches.
Voollen Felt	71	36	16	7	4.3
awdust	100	55	26	11	7
oal-ashes	172	110	60	27	16.6

Condensation.

Tredgold ascertained by experiment that steam at pressure (absolute) f 17.5 lbs. per sq. inch, 221°, produced 1 cube foot of water per hour y condensation in 182 sq. feet of cast-iron pipe, at a uniform and quiscent temperature of 60°. Hence, condensation .352 lb. water per our, or .0022 lbs. per degree of difference of temperature (221 − 60).

From experiments of Mr. B. G. Nichol in England, 1875, it was deduced:

That rates of transmission of heat, between temperature of steam and hat of water of condensation at its exit, at the rate of 150 feet per minute, nay be taken as 380 units for vertical tubes and 520 for horizontal.

Condensation of Steam in Cast-iron Pipes. (*M. Burnat.*)

Average Press. per Sq. Inch.	Temperature.			Condensation per sq. foot of external surface of pipe per hour.				
	Steam.	Air.	Difference.	Bare.	Straw.	Pipe.	Waste.	Plaster.
Lbs.	°	°	°	Lb.	Lb.	Lb.	Lb.	Lb.
22	233	36.5	196.5	.581	.2	.229	.286	.324

From these data, following constants are deduced for an absolute pressure of 2 lbs. per sq. inch of steam condensed, and heat passed off per sq. foot of external urface of pipe per hour of 1° difference of temperature.

Surface of Pipe.	Steam condensed per Sq. Foot.	Heat passed off.	Surface of Pipe.	Steam condensed per Sq. Foot.	Heat passe off
	Lb.	Units.		Lb.	U
re pipe	.003	2.812	Cotton waste 1 inch	.001 46	[illegible]
aw coat	.001 02	.968	Earth and hair	.001 65	[illegible]
ed with clay pipe	.001 15	1.108	White paint	.001 56	[illegible]

Pipes were 4.72 ins. diameter, .25 inch thick, and had area of 58.5 sq. feet. *Bare*—rough surface as cast. *Straw coat*—laid lengthwise .6 inch thick and bound. *Pipe*—laid in clay pipe with an air space between them, the whole covered with loam and straw. *Waste cotton*—1 inch thick and bound with twine. *Plaster*—laid in clay and hair 2.36 ins. thick.

A wrought-iron pipe 3.75 ins. in external diameter, .25 inch thick, and lagged with felt and spun yarn .5 inch thick, condensed steam at 245° at rate of .[illegible] lb. per sq. foot per hour, in an external temperature of 60°.

Steam Condensed per Sq. Foot and per Degree per Hour.

Mean Results of several Experiments with bare Cast-iron Pipes, with Steam at Absolute Pressure of 20 lbs. per Sq. Inch.

.4 lb. per sq. foot, and .002 39 lb. per degree.

Hence, to ascertain quantity of heat lost by condensation of .002 39 lb. $= \frac{1}{420}$ of a lb.

Difference of total and sensible heats of 1 lb. steam at 20 lbs. absolute pressure $= 1151° + 32° - 228° = 955$ units, and $955 \div 420 = 2.274$ units $=$ *heat condensed.*

The loss of heat from a naked boiler in air at 62°, under an absolute pressure of 30 lbs. per sq. inch, was 5.8 units.

Congelation and Liquefaction.

Freezing water gives out 140° of heat. All solids absorb heat when becoming fluid.

Particular quantity of heat which renders a substance fluid is termed its caloric of fluidity, or latent heat.

Temperature of Solidification of Several Gases. (*Faraday.*)

Cyanogen........... 31°	Ammonia......... 103°	Sulphuretted Hydrogen, 122°
Carbonic Acid....... 72°	Sulphurous Acid... 105°	Protoxide of Nitrogen.. 145°

Frigorific Mixtures.

Mixtures.	Parts.	Fall of Temperature.
Sea salt	5	° °
Nitrate of ammonia	5	−18 to −25
Snow, or pounded ice	12	
Muriate of ammonia / Nitrate of potash	5	−5 to −18
Snow, or pounded ice	1	
Phosphate of soda	3	
Nitrate of ammonia	2	−34 to −50
Dilute mixed acids	4	
Snow	1	−40 to −73
Crystallized muriate of lime	3	
Snow	8	−68 to −91
Dilute sulphuric acid	10	
Phosphate of soda	5	
Nitrate of ammonia	3	0 to −34
[illegible] nitric acid	4	
[illegible]	3	0 to −46
[illegible] acid	2	

Mixtures.	Parts.	Fall of Temperature.
Nitrate of ammonia	1	°
Water	1	+50 to +4
Snow	1	−10 to −60
Dilute sulphuric acid	1	
Sulphate of soda	3	+50 to −3
Diluted nitric acid	2	
Nitrate of ammonia	1	
Carbonate of soda	1	+50 to −7
Water	1	
Sulphate of soda	6	
Muriate of ammonia	4	+50 to −10
Nitrate of potash	2	
Dilute nitric acid	4	
Phosphate of soda	9	+50 to −12
Dilute nitric acid	4	
Snow	3	+20 to −48
Muriate of lime	4	
Potash	4	+32 to −[illegible]
Snow	3	

[illegible]bonic Acid and Sulphuric Ether, under receiver of an [illegible] lbs. to 14 lbs., exhibited a temperature ranging [illegible] most intense cold as [illegible] known. (Faraday.)

Melting-points.

Metals.	°
ıminum	1400
timony	810
senic	365
smuth	476
onze	1692
lcium at red heat	—
pper	1996
ld, pure	2282 2590
' standard	2156
on, cast	2000 2250 3479*
' 2d melting	2200 2450 3700*
' Wrought	2700 2912 3509*
' malleable forge	—
ad	608
thium	356
ercury	—39
atinum	—
ickel, highest forge heat	—
tassium	136
lver	1250 1873
dium	194
eel	2500
n	446
inc	680
Alloys.	
ead 2, Tin 3, Bismuth 5	212
" 1, " 3, " 5	210

Alloys.	°
Lead 1, Tin 4, Bismuth 5	240
" 2, " 3	334
" 3, " 2, Bismuth 5	199
" 3, " 1	552
" 2, " 1 (solder)	475
" 1, " 2 (soft solder)	360
" 1, " 1	368
" 1, " 1, Bism. 4, Cadm. 1	155
Tin 1, Bismuth 1	286
" 2, " 1	336
" 8, " 1	392
Zinc 1, Tin 1	399
Fusible Plugs.	
Lead 2, Tin 2	372
" 6, " 2	383
" 7, " 2	388
" 8, " 2	410
Various Substances.	
Ambergris	145
Beeswax	151
Carbonic acid	—108
Glass	2377
Ice	32
Lard	95
Nitro-Glycerine	45
Phosphorus	112
Pitch	91
Saltpetre	606
Spermaceti	112
Stearine	114
Sulphur	239
Tallow	92
Wax, white	142

* Rankine.

Volume of Water, Antimony, and Cast iron, in the solid state, exceeds ıat of the liquid, as evidenced by the floating of ice on water, and of cold on on iron in a liquid state.

Boiling-points. (*Under One Atmosphere.*)

Liquids.	°
cohol, s. g. 813	173
nmonia	140
nzine	173
loroform	146
her	100
nseed oil	597
rcury	648
lk	213
tric acid, s. g. 1.42	248
" " " 1.5	210
of Turpentine	315
troleum, rectified	316
osphorus	554
water, average	213.2
phur	570
huric acid, s. g. 1.848	590
" " " *1.3*	240
ether	100

Liquids.	°
Turpentine	315
Water	212
" in vacuo	98
Whale oil	630
Saturated Solutions.	
Acetate of Soda	255.8
" " Potash	336
Brine	226
Carbonate of Soda	220.3
" " Potash	275
Nitrate of Soda	250
" " Potash	240.6
Salt, common	227
Various Substances.	
Coal Tar	
Naphtha	

Pressure of Saturated Vapors under Various Te atures. (*Regnault.*)

Temperature.	Water.	Alcohol.	Ether.	Chloroform.	Temperature.	Water.	Alcohol.	Ether.
°	Lbs.	Lbs.	Lbs.	Lbs.	°	Lbs.	Lbs.	Lbs.
32	.089	.246	3.53	—	212	14.7	32.6	95.17
50	.178	.466	5.54	2.52	230	20.8	45.5	120.9
68	.337	.851	8.6	3.68	240.8	25.37	—	137
86	.609	1.52	12.32	5.34	248	29.88	62.05	—
104	1.06	2.59	17.67	7.04	266	39.27	83.8	—
122	1.78	4.26	24.53	10.14	276.8	46.87	—	—
140	2.88	6.77	33.47	14.27	284	52.56	109.1	—
158	4.51	10.43	44.67	18.88	302	69.27	140.4	—
176	6.86	15.72	57.01	26.46	305.6	73.07	147.3	—
194	10.16	23.02	75.41	35.03	320	89.97	—	—

Boiling-points of Water corresponding to Altitudes of Barometer l 62 and 31 Ins.

Barom.	Boiling-point.	Barom.	Boiling-point.	Barom.	Boiling-point.	Barom.	Bo
	°		°		°		
26	204.91	27.5	207.55	29	210.19	30.5	
26.5	205.79	28	208.43	29.5	211.07	32	
27	206.67	28.5	209.31	30	212		

Boiling-point of Salt water, 213.2°. Water may be heated in a to 400° without boiling.

Fluids boil in a vacuum with less heat than under pressure of atm On Mont Blanc water boils at 187°; and in a vacuum water boils a 100°, according as it is more or less perfect.

Water may be reduced to 5° if confined in tubes of from .003 to .005 inch eter: this is in consequence of adhesion of water to surface of tube, interfe a change in its state. It may also be reduced in its temperature below 3 kept perfectly quiescent.

Effect upon Various Bodies by Heat.

Wedgewood's zero is 1077° (Fahrenheit), and each degree = 130°.

In designation of degrees of temperature, symbol + is omitted when tem is above 0; but when below it, symbol — must be prefixed.

	Degrees.
Acetification ends....	88
Acetous fermentation begins.. ...	78
Air Furnace.........	3300
Ammonia (liq.) freezes	—46
Blood (hum.), heat of.	98
" freezes.	25
Brandy freezes.......	—7
Charcoal burns.......	800
Cold, greatest artific.	—166
" " natural	—56
Common fire.........	790
Fire brick....4000 to	5000
Gutta-percha softens..	145
Heat, cherry red	1500
" " (Daniell)	1141
" bright red......	1860
visible by	1077
....	2900

	Degrees.
Highest natural temperature, Egypt..	117
India-rubber and Gutta-percha vulcanize..........	293
Iron, bright red in the dark.........	752
Iron, red hot in twilight	884
Iron, wrought, welds..	2700
Ignition of bodies....	750
Combustion of do...	800
Mercury volatilizes...	680
Milk freezes.........	30
Nitric Acid (sp. grav. 1.424) freezes....	—45
Nitrous Oxide freezes	—150
Olive-oil freezes......	36
Petroleum boils......	306
Proof Spirit freezes...	—7

Sea-water freezes
Snow and Salt, equ parts..........
Spirits Turpen. fre
Steel, faint yellow.
" full " .
" purple......
" blue........
" full blue....
" dark " ....
" polished, blu
" " straw c
Strong Wines freez
Sulph. Acid (sp. grav 1.641) freezes...
Sulph. Ether freeze
Vinegar freezes....
Vinous ferment...6
Zinc boils..........
Wood, dried......

Liquids at their Boiling

Steam.		Steam.	
.... 528	1 Ether	298	1 Tu

ght corresponding to Boiling-point of Pure Water.

Boiling-point at Level of Sea = 212°.

.	Feet.	Degree.	Feet.	Degree.	Feet.	Degree.	Feet.	Degree.	Feet.
	521	207	2625	203	4761	199	6929	195	9129
	1044	206	3156	202	5300	198	7476	194	9684
	1569	205	3689	201	5841	197	8025	193	10241
	2096	204	4224	200	6384	196	8576	192	10800

rection for temperature of air same as given at page 428 for Elevation Barometer by multiplying by C.

ISTRATION.—If water boils at a temperature of 200° and C = 136°,

Then $6384 \times 1.08 = 6894.72$ *feet.*

Underground Temperature.

an increase of underground temperature per foot, from observations in nes in various and extended localities, is .01565° = 1° in 64 feet.

ear Expansion or Dilatation of a Bar or Prism by Heat.

For 1° in a Length of 100 Feet.

METALS, MINERALS, ETC.

	Inch.		Inch.
ony	.00722	Iron, from 32° to 572°	.00326
th	.00928	Iron wire	.00823
	.0125	Lead	.019
yellow	.0126	Marble	.00566
	.00144	Palladium	.00667
ron	.0074	Platinum	.00571
ıt	.00956	" from 32° to 572°	.00204
r from 0° to 212°	.0115	Sandstone	.013
from 32° to 572°	.00418	"	.00814
rick	.0033	Silver	.0127
	.00574	Speculum metal	.013
lint	.00541	Steel, rod	.00763
ube	.0612	" cast	.0072
-Paris standard annealed	.0101	" tempered	.00826
" " unannealed	.0103	" not tempered	.00719
:e	.00525	Tin	.0145
Ietal—16 copper + 1 tin	.0127	Water	.0002229
" 8 copper + 1 tin	.0121	White Solder—tin 1 + 2 lead	.0167
	.0333	Zinc, forged	.0207
forged	.00814	" sheet	.0196
from 0° to 212°	.00788	" 8 + 1 tin	.0179

perficial expansion is twice linear, and cubical, three times linear.

To Compute Linear Expansion of a Substance.

vide 1 by decimal given in above Table, and quotient will give pro- on.

JSTRATION 1.—A rod of copper 100 feet in length will expand between tem- ıres of 32° and 212°. $212 - 32 = 180 \times .0115 = 2.07$ *ins.*

A cube of cast iron of 1 foot will expand in volume between temperatures of ıd 212°. $212 - 62 = 150$, and $150 \times .0074 = 1.11$, which ÷ 100 for 1 foot = *inch*, and $12 + .0111 \times 3 = 12.0333$ *ins.*

ıe solids, as ice, cast iron, etc., have more volume when near to their melting- than when melted. This is illustrated in floating of solid metal in the liquid

Expansion of Water.

ter expands from temperature of maximum density (see page *to 46°, at which degree it* regains its initial volume of 32°, and *it expands under one* atmosphere to 212°; and its cubical exp. *that is, its volume is dilated* from 1 at 32° to 1.0466 at 212°. *pansion increases* in a greater ratio than that of temperature.

To Compute Density of Water at a given Temperature.

$$\frac{62.5 \times 2}{\frac{t+461}{500} + \frac{500}{t+461}} = \textit{approximate density, } t \textit{ representing temperature of water.}$$

ILLUSTRATION.—What is density of pure water at 298°?

$$\frac{62.5 \times 2}{\frac{298+461}{500} + \frac{500}{298+461}} = 57.42 \textit{ lbs. or weight of 1 cube foot.}$$

Expansion of Water. (*Dalton.*)

Temp.	Expansion.	Temp.	Expansion.	Temp.	Expansion.	Temp.	Expansion.
°		°		°		°	
22	1.0009	52	1.00021	112	1.0088	172	1.02575
32	1	72	1.0018	132	1.01367	192	1.03265
*40	1	92	1.00477	152	1.01934	212	1.0466

* Greatest density 39.1°.

Hence, at 72°, water expands $\frac{1}{.0018} = 555.55$th part of its original bulk.

Expansion of Liquids from 32° to 212°. *Volume at 32° = 1.*

Liquids.	Volume at 212°.	Liquids.	Volume at 212°.
Alcohol	1.11	Olive oil	1.08
Linseed oil	1.08	Sulphuric acid	1.06
Mercury	1.0154	" ether	1.07
" 212° to 392°	1.018 433 1	Turpentine	1.07
" 392° to 572°	1.018 867 9	Water	1.0466
Nitric acid	1.11	Water sat. with salt	1.05

Expansion of Gases from 32° to 212°. *Volume at 32° = 1.*

Gases.		Volume at 212°.	Gases.		Volume at 212°.
Air	1 Atmosphere	[illegible]	Nitrous oxide	1 Atmosphere	1.3719
	[illegible] "	[illegible]	Sulphurous acid	1 "	1.3903
Hydrogen	1 "	[illegible]		1.16 "	1.398
	[illegible] "	[illegible]	Carbonic oxide	1 "	1.3669
Carbonic acid	1 "	[illegible]	Cyanogen	1 "	1.3877
	[illegible] "	[illegible]			

Expansion of Gases is uniform for all temperatures.

Volume of One Pound of Various Gases at 32° under one Atmosphere.

	Cubic feet.		Cubic feet.		Cubic feet.
Air	[illegible]	Hydrogen	[illegible]	Oxygen	[illegible]
Carbonic acid	[illegible]	Nitrogen	[illegible]	Mercury	[illegible]
Ether, vapor	[illegible]	Olefiant	[illegible]	Steam	[illegible]

Expansion of Air. (*Dalton.*)

Temp.	Expansion.	Temp.	Expansion.	Temp.	Expansion.	Temp.	Expansion.	Temp.	Expansion.	Temp.	Expansion.
°		°		°		°		°		°	
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Compute Volume of a Constant Weight of Air or Permanent Gas for any Pressure.

[illegible]

Relative Densities of some Vapors.

ater 1. Alcohol 2.59. Ether 4.16. Spirits of Turpentine 8.06. Sulphur 3.59.

lume, Pressure, and Density of Air at Various Temperatures.

Volume and Atmospheric Pressure at 62° = 1.

per-re.	Volume of 1 lb. of air at atmospheric pressure of 14.7 lbs.	Pressure of a given weight of air.	Density, or weight of one cube foot of air at 14.7 lbs.	Temperature.	Volume of 1 lb. of air at atmospheric pressure of 14.7 lbs.	Pressure of a given weight of air.	Density, or weight of one cube foot of air at 14.7 lbs.
°	Cube feet.	Lbs. per Sq. Inch.	Lbs.	°	Cube feet.	Lbs. per Sq. Inch.	Lbs.
0	11.583	12.96	.086 331	360	20.63	23.08	.048 476
2	12.387	13.86	.080 728	380	21.131	23.64	.047 323
0	12.586	14.08	.079 439	400	21.634	24.2	.046 223
0	12.84	14.36	.077 884	425	22.262	24.9	.044 92
2	13.141	14.7	.076 097	450	22.89	25.61	.043 686
0	13.342	14.92	.074 95	475	23.518	26.31	.042 52
0	13.593	15.21	.073 565	500	24.146	27.01	.041 414
0	13.845	15.49	.072 23	525	24.775	27.71	.040 364
0	14.096	15.77	.070 942	550	25.403	28.42	.039 365
0	14.592	16.33	.068 5	575	26.031	29.12	.038 415
0	15.1	16.89	.066 221	600	26.659	29.82	.037 51
0	15.603	17.5	.064 088	650	27.915	31.23	.035 822
0	16.106	18.02	.062 09	700	29.171	32.635	.034 28
0	16.606	18.58	.060 21	750	30.428	34.04	.032 865
0	16.86	18.86	.059 313	800	31.684	35.445	.031 561
2	16.91	18.92	.059 135	850	32.941	36.85	.030 358
0	17.111	19.14	.058 442	900	34.197	38.255	.029 242
0	17.612	19.7	.056 774	950	35.454	39.66	.028 206
0	18.116	20.27	.055 2	1000	36.811	41.065	.027 241
0	18.621	20.83	.053 71	1500	49.375	55.115	.020 295
0	19.121	21.39	.052 297	2000	61.94	69.165	.016 172
0	19.624	21.95	.050 959	2500	74.565	83.215	.013 441
0	20.126	22.51	.049 686	3000	87.13	97.265	.011 499

Compute Volume of a Constant Weight of Air or other Permanent Gas for any other Pressure and Temperature.

Vhen volume is known at a given pressure and temperature. RULE.—Muly given volume by given pressure, and by new absolute temperature, divide by new pressure, and by given absolute temperature.

XAMPLE.—Given volume 16.91 cube feet, pressure 13.86 lbs., and temperature ; what is volume at this temperature?

emperature for volume 16.91 = 212°.

$$16.91 \times 13.86 \times \overline{32 + 461} \div 13.86 \times \overline{212 + 461} = 12.39 \textit{ cube feet.}$$

Compute Pressure of a Constant Weight of Air or other Permanent Gas for any other Volume and Temperature.

Then pressure is known for a given volume and temperature. RUI tiply given pressure by new absolute temperature, and divide by lute temperature.

TE.—Absolute temperature is found by adding 461° to temperature.

MPLE.—Given pressure 13.86 lbs., and temperature at this volume 32°; *sure at temperature of 212°?*

$$13.86 \times \overline{212 + 461} \div \overline{32 + 461} = 18.92 \text{ lbs.}$$

X x*

To Compute Volume of a Constant Weight of other Permanent Gas at any Temperatur

When volume at a given temperature is known, pressure being RULE.—Multiply given volume by new absolute temperature, ar by given absolute temperature.

Absolute zero-point by different thermometrical scales is: Fahrenheit Reaumur —219.2°; Centigrade —274°.

EXAMPLE.—Volume of 1 lb. air at 32° = 12.387 cube feet; what is its 212°?

$$12.387 \times \overline{212 + 461} \div \overline{32 + 461} = 16.91 \textit{ cube feet.}$$

To Compute Increased Volume of a Constant of Air.

When initial volume at 62° = 1 under 1 atmosphere. RULE.— temperature add 461, and divide sum by 523 (62 + 461).

EXAMPLE.—Assume elements of preceding case.

$$212° + 461 \div 523 = 1.287 \textit{ comparative volume to } 1.$$

To Compute Pressure of a Constant Weight of other Gas at 62°, and at 14.7 lbs. Pressure per S with Constant Volume, for a given Temperatu

RULE.—Add 461 to given temperature, and divide sum by 35.58.

EXAMPLE.—Temperature is 212°; what is pressure?

$$212 + 461 \div 35.58 = 18.92 \textit{ lbs.}$$

To Compute Volume, Pressure, Temperature, Density of Air.

$$\frac{t + 461}{p\ 2.71} = V; \qquad \frac{t + 461}{39.8} = V; \qquad \frac{t + 461}{V\ 2.71} = p; \qquad V\ 2.7074\ p - 461 =$$

$2.71 \dfrac{p}{t + 461} = D.$ *t representing temperature, p pressure in lbs. per sq. inc ume in cube feet, and* D *weight of* 1 *cube foot at* 14.7 *lbs. per sq. inch.*

Product of volume and pressure of a constant weight of air, or an permanent gas, is equal to product of absolute temperature and a coe determined for each gas by its density.

$$\text{Or, } V\,p = C\,\overline{t + 461}.$$

Coefficients, as determined by volumes and consequent densities.*

Air	2.71	Hydrogen	.1875	Oxygen	
Carbonic acid	4.14	Nitrogen	2.63	Mercury	
Ether, vapor	7.02	Olefiant	2.67	Steam	

* See D. K. Clark, London, 1877, page 349.

Decrease of Temperature by Altitudes.

	In clear sky.	With cloud
From 1 to 1 000 feet	1° in 139 feet	1° in 22
1 " 10 000 "	1° " 288 "	1° " 33
1 " 20 000 "	1° " 365 "	1° " 46

Compute Temperature to which a Substance n Length or Dimension must be Submitte ed, to give it a Greater or Less Length or Expansion or Contraction.

n Length is to be increased. $\dfrac{L - l}{C} + t = T.$ L and

... in like denomination

ION.—A copper rod at 32° is 100 feet in length; to what temperature ıbjected to increase its length 1.1633 ins.?

ı for a length of 100 feet of copper for 1° = .0115.

$$\frac{100 \times 12 + 1.1633 - \overline{100 \times 12}}{.0115} + 32 = \frac{1.1633}{.0115} + 32 = 133.16^{\circ}.$$

ngth is to be reduced. $\frac{L - l}{C} - T = t.$

ION.—Take elements of preceding case.

$$\frac{1201.1633 - 1200}{.0115} - 133.16^{\circ} = 101.16 - 133.16 = 32^{\circ}.$$

ıce Degrees of Fahrenheit to Reaumur and Centigrade, and Contrariwise.

ıheit to Reaumur. *If above zero.*—Multiply difference mber of degrees and 32 by 4, and divide product by 9.

' $- 32^{\circ} = 180^{\circ}$, and $180^{\circ} \times 4 \div 9 = 80^{\circ}$.

zero.—Add 32 to number of degrees; multiply sum by 4, and .uct by 9.

$^{\circ} + 32^{\circ} = 72^{\circ}$, and $72^{\circ} \times 4 \div 9 = -32^{\circ}$.

ıur to Fahrenheit. *If above freezing-point.*—Multiply degrees by 9, divide by 4, and add 32 to quotient.

$\times 9 \div 4 = 180^{\circ}$, and $180^{\circ} + 32 = 212^{\circ}$.

freezing-point.—Multiply number of degrees by 9, divide by 4, ːt 32 from product.

$^{\circ} \times 9 \div 4 = 72^{\circ}$, and $72^{\circ} - 32 = -40^{\circ}$.

ıheit to Centigrade. *If above zero.*—Multiply difference .mber of degrees and 32 by 5, and divide product by 9.

$- 32^{\circ} \times 5 \div 9 = 180^{\circ} \times 5 \div 9 = 100^{\circ}$.

zero.—Add 32 to number of degrees, multiply sum by 5, and .uct by 9.

$^{\circ} + 32^{\circ} \times 5 \div 9 = 72^{\circ} \times 5 \div 9 = -40^{\circ}$.

rade to Fahrenheit. *If above freezing-point.*—Multiply degrees by 9, divide product by 5, and add 32 to quotient.

$\times 9 \div 5 = 180^{\circ}$, and $180^{\circ} + 32 = 212^{\circ}$.

freezing-point.—Multiply number of degrees by 9, divide product ake difference between 32 and quotient.

$^{\circ} \times 9 \div 5 = 18^{\circ}$, and $18^{\circ} \backsim 32 = 14^{\circ}$.

ıur to Centigrade.—Divide by 4, and add product.

$\div 4 = 20^{\circ}$, and $20^{\circ} + 80^{\circ} = 100^{\circ}$.

rade to Reaumur.—Divide by 5, and subtract product.

$\div 5 = 20^{\circ}$, and $100^{\circ} - 20 = 80^{\circ}$.

Corresponding Degrees upon the Three Scales.

ent.	Reaum.	Fahr.	Cent.	Reaum.	Fahr.	Cent.	Reaum.
100	80	32	0	0	—40	—40	—32

ompute Expansion of Fluids in Volume.

oceed by preceding formulas for computing length of a su titute V and v for volume, instead of L *and* l, the lengths.

ing length of pipe for any given space it is proper to include tation the character and occupancy of the space. Thus, a ; hours of service, or a dwelling-room, will require less service gth of pipe than a hallway or a public building.

f Heat by Surfaces of Glass or Metal.—In addition to the to be heated per minute for each occupant, 1.25 cube feet for of glass or metal the space is enclosed with must be added. cating power of the glass and metal being directly proportion-ce of external and internal temperature of the air. Thus, 80 'ill reduce 100 feet of air per minute.

s are laid in Trenches in the Earth.—The loss of heat is es-r. Hood at from 5 to 7 per cent.

of Water in Pipes.—In consequence of the complex forms of and the roughness of their internal surface, it is impracticable e to determine the velocity of circulation, as consequent upon reights of ascending and descending columns of the water.

'ence of temperature in the two columns of 30° (190° — 160°) of 20 feet, the velocity due to the height would be 3.74 feet. ot .3, and in some cases but .1, would be attained.

and Large Public Rooms, with ordinary area of doors and windows ventilation, a large amount of heat is generated by the respiration assembled therein.

s it is not necessary to heat the air above 55°, and a rule that will iary ranges of temperature from 10° is to divide volume in cube l quotient will give area of plate in sq. feet or length of 4-inch pipe

r required per Hour for each Occupant in an Enclosed Space.
(*General Morin.*)

Cube Feet.		Cube Feet.		Cube Feet.
:100 to 3700	Lecture-rooms	1000 to 2100	Prisons.......	1800
:100 " 3500	Theatres......	1400 " 1800	Schools.......	424 to 1060

ıte Length of Iron Pipe required to Heat Air in an Enclosed Space.

By Hot Water.

ıltiply volume of air to be heated per minute in cube feet by ɜmperatures in space and external air, divide product by differ-ratures of surface of pipe and space, multiply result by follow-s, and product will give length of pipe in feet.

er of 4 ins. multiply by .5 to .55, for 3 ins. by .7 to .75, and for 1.1.

ıs. in diameter, .375 inch thick, and 1 foot in length has an al surface of 1.05 *sq. feet.*

'olume of a room of a protected dwelling is 4000 cube feet; what . pipe, at 200°, is necessary to maintain a temperature of 70°, when at 0°?

$$\frac{4000 \times \overline{70 - 0}}{200 - 70} \times .4 = 862 \textit{ feet.}$$

ng length of pipe or surface ' ' 'a to be borne in mind *'ients here given and comp* 'r table are base *tion or change of air or* 'ibe feet *m 5 to 10 cube feet in* *is restricted the coeffic*

th temperature, 1 sq. meter (10.76 sq. feet) of [illegible] (2472 cube feet) = 4.35 sq. feet or 5.11 lineal [illegible]

transverse section of 260 sq. feet, with a window- it is customary in France to assign 1.33 sq. feet f shop = 5.2 sq. feet per 1000 cube feet.

Heating by Steam. (*R. Briggs, M. I. C. E.*)

...ding halls and vaults............	286
....	137 370 sq. feet.
....	1 923 500 cube feet.
....	650
...s at any time..................	1300
...ng vaults......................	1443 cube feet.

grate surface and 8000 sq. feet of heating surface. the above, to operate the elevators and electric applying steam to heat a distant building, requiring

By Steam.

. of Iron Pipe required to Heat Air Space, with Steam at 5 lbs. per Sq. sure of Atmosphere.

me of air in cube feet to be heated per minute, by in space and external air, divide product by coeffi-, and quotient will give length of 4-inch pipe in te-surface in sq. feet.

t 5 lbs. + pressure = 228°. Hence, if temperature of space or 120°, the differences will be 168°, 158°, 148°, and 108°, f .5, as given in rule for hot water, would be 336, 316, 296, . in diameter, and for

	60°	70°	80°	120°
ch pipe........	252	237	222	162
"	168	158	148	108
"	84	79	74	54

me of combined spaces of a factory is 50 000 cube feet; what plate at 200° is necessary to maintain a temperature of 50° 0°?

$$\frac{0000 \times \overline{50-0}}{200-50} \times .4 = 6666 \textit{ square feet.}$$

d per Hour to Heat 100 Feet of Pipe.

(*Chas. Hood.*)

fference of Temperature of Pipe and Air in Space, in Degrees.

135	130	125	120	115	110	105	100	95	90	85	80
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	1	.9	.9	.9	.8	.8	.7	.7	.7	.6	.6
2.1	2	1.9	1.8	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.2
3.1	3	2.9	2.8	2.7	2.5	2.4	2.3	2.2	2.1	2	1.8
4.2	4.1	3.9	3.7	3.6	3.4	3.2	3.1	2.9	2.8	2.6	2.5

rding to M. Claudel, 43 feet in width by 10.5 high, a single ins. in diameter per foot of length of room, appears to be ...ue being from 170° to 180°. being at 180°, fference of 120°, it is conve from 1.5 ed surface as equivalent to heated to 9 sq. feet of hot-water o cube

sq. feet of cast-iron pipe- 194°, will warm 1000 cul. Steam is condensed at r.

(R. L. Greene.) Length of fronts of buildings	2 000 [illegible]	
Total volume of rooms	2 574 084 cube feet	
Radiating surfaces, direct, 10 804	34 100 sq. feet	
indirect, 23 290		
Boilers.—Grate-surface	130	"
Heating surface	5 863	"

Volume of Air Heated by Radiators; Consumption of Coal; Areas of Grate and Heating-surface of Boilers.

(Rob't Briggs.)

Per 100 Sq. Feet of Warming-surface of Radiator.

Pressure of steam per sq. inch above atmosphere in lbs.	—	3	10	30	60
Heat from radiators per minute in units	450	486	537	642	7[illegible]
Volume of air heated per minute in cub. feet	25 110	26 772	29 570	35 352	40[illegible]
Efficiency of radiators in ratio	1	1.006	1.178	1.408	1.6[illegible]
Coal consumed per hour in lbs.	3.24	3.24	3.58	4.28	4.9[illegible]
Area of grate consuming 8 lbs. coal per hour in sq. feet	.38	.405	.448	—	—
[illegible] lbs.	—	—	.298	.357	.4[illegible]
Heating surface of boiler, coal consumed per hour [illegible] in sq. feet	8.512	9.072	10.02	11.98	13.[illegible]
[illegible] lbs. [illegible]	22.4	22.4	22.4	—	—
[illegible] lbs. [illegible]	—	—	33.6	33.6	33.6

By Hot-Air Furnaces or Stoves.

A square foot of heating surface in a hot-air furnace or stove is held to be equivalent to [illegible] sq. feet of hot water pipe.

M. Péclet deduced that when the flue-pipe of a stove radiated its heat directly to air of a space, the heat radiated per sq. foot per hour, for 1° difference of temperature, were, for: Cast iron, 3.05 units; Wrought iron, 1.6[illegible] [illegible] and Terra cotta [illegible] inch thick, 1.42 units.

In ordinary practice, 1 sq. foot of cast iron is assigned to 328 cube feet of space.

Open Fires.

According to M. Claudel, the quantity of heat radiated into an apartment from an ordinary fireplace is .25 of total heat radiated by combustible.

For wood the heat utilized is but from 6 to 7 per cent., and for coal 13 per cent.

In combustion of wood, chimney of an ordinary open fireplace draws from 1000 to 1600 cube feet of air per pound of fuel, and a sectional area of from 50 to 60 sq. ins. is sufficient for an ordinary apartment.

Proportions of fuel required to heat an apartment are: For ordinary fireplaces, 100; metal stoves, 63; and open fires, 13 to 16.

Furnaces.

By D. K. Clark, from investigations of Mr. J. Lothian Bell.

Cupola.—M. Péclet estimates that in melting pig-iron by combustion of 10 per cent. of its weight of coke, 14 per cent. only of the heat of coke is utilized.

[illegible]al.—According to Dr. Siemens, 1 ton of coal is c[illegible] [illegible] of wrought iron to welding-point of 2700°, a[illegible] [illegible]ating up 39 tons of iron; from which it ap[illegible] [illegible] [illegible]ole heat is appropriated by the iron. Si[illegible] [illegible] [illegible]at generated is utilized in r[illegible]

ı ordinary furnaces, whilst, in his regenerative furnace, 1 ton of steel ;ed by combustion of 1344 lbs. of small coal, showing that 6 per cent. heat is utilized.

ıst-furnace.—Mr. Bell has formed detailed estimates of appro-n of the heat of Durham coke in a blast-furnace; from which is de-following abstract:

ham coke consists of 92.5 per cent. of carbon, 2.5 of water, and 5 of d sulphur. To produce 1 ton of pig-iron, there are required 1232 lbs. stone, and 5388 lbs. of calcined iron-stone; the iron-stone consists of bs. of iron, 1008 lbs. of oxygen, and 2509 lbs. of earths. There is l 813 lbs. of slag, of which 123 lbs. is formed with ash of the coke, o lbs. with the limestone. There are 2397 lbs. of earths from the iron-less 93 lbs. of bases taken up by the pig-iron and dissipated in fume, 14 lbs. Total of slag and earths, 3127 lbs.

Bell assumes that 30.4 per cent. of the carbon of the fuel, which es-in a gaseous form, is carbonic acid; and that, therefore, only 51.27 nt. of heating power of fuel is developed, and remaining 48.73 per eaves tunnel-head undeveloped. He adopts, as a unit of heat, the quired to raise the temperature of 112 lbs. of water 33.8°.

HYDRAULICS.

cending Fluids are actuated by same laws as *Falling Bodies.*

'luid will fall through 1 foot in .25 of a second, 4 feet in .5 of a l, and through 9 feet in .75 of a second, and so on.

ocity of a fluid, flowing through an aperture in side of a vessel, oir, or bulkhead, is same that a heavy body would acquire by fall-eely from a height equal to that between surface of fluid and : of aperture.

ocity of a fluid flowing out of an aperture is as square root of of head of fluid. *Theoretical* velocity, therefore, in feet per sec-s as square root of product of space fallen through in feet and $= \sqrt{2gh}$; consequently, for one foot it is $\sqrt{64.333} = 8.02$ *feet.* velocity, however, of a number of experiments gives 5.4 feet, of theoretical velocity.

hort ajutages accurately rounded, and of form of contracted vein, *contracta*), coefficient of discharge = .974 of theoretical.

s subside to a natural level, or curve similar to Earth's convexity; apparent r level taken by any instrument for that purpose, is only a tangent to Earth's ference; hence, in leveling for canals, etc., difference caused by Earth's cur- must be deducted from apparent level, to obtain true level.

ıctions from Experiments on Discharge of Fluids from Reservoirs.

hat volumes of a fluid discharged in equal times by same apertures ame head are nearly as areas of apertures.

hat volumes of a fluid discharged in equal times by similar apertu *different heads, are nearly as* square roots of corresponding h *above surface of apertures.*

ıt, on account of friction, small-lipped or thin orifices dischar *'y more fluid than* those which are larger and of similar *ıe height of fluid.*

4. That in consequence of a slight augmentation which contraction of the fluid vein undergoes, in proportion as the height of a fluid increases, the flow is a little diminished.

5. That if a cylindrical horizontal tube is of greater length than its diameter, discharge of a fluid is much increased, and may be increased with advantage, up to a length of tube of four times diameter of aperture.

6. That discharge of a fluid by a vertical pipe is augmented, on the principle of gravitation of falling bodies; consequently, greater the length of a pipe, greater the discharge of the fluid.

7. That discharge of a fluid is inversely as square root of its density.

8. That velocity of a fluid line passing from a reservoir at any point is equal to ordinate of a parabola, of which twice the action of gravity (2 g) is parameter, the distance of this point below surface of reservoir being the abscissa.* Or, velocity of a jet being ascertained, its curve is a parabola, parameter of which $= 4\,h$, due to velocity of projection.†

9. Volume of water discharged through an aperture from a prismatic vessel which empties itself, is only half of what it would have been during the time of emptying, if flow had taken place constantly under same head and corresponding velocity as at commencement of discharge; consequently the time in which such a vessel empties itself is double the time in which all its fluid would have run out if the head had remained uniform.

10. Mean velocity of a fluid flowing from a rectangular slit in side of a reservoir is two thirds of that due to velocity at sill or lowest point, or to that due to a point four ninths of whole height from surface of reservoir.

11. When a fluid issues through a short tube, the vein is less contracted than in preceding case, in proportion of 16 to 13; and if it issues through an aperture which is alike to frustum of a cone, base of which is the aperture, the height of frustum half diameter of aperture, and area of small end to area of large end as 10 to 16, there will be no contraction of the vein. Hence this form of aperture will give greatest attainable discharge of a fluid.

12. Velocity of efflux increases as square root of pressure on surface of fluid.

13. In efflux under water, difference of levels between the surfaces must be taken as head of the flowing water.

14. To attain greatest mechanical effect, or *vis viva*, of water flowing through an opening, it should flow through a circular aperture in a thin plate, as it has less frictional surface.

From Conduits or Pipes. (*Bossut.*)

1. Less diameter of pipe, the less is proportional discharge of fluid.

2. Discharges made in equal times by horizontal pipes of different lengths, but of same diameter, and under same altitude of fluid, are to one another in inverse ratio of sq. roots of their lengths.

3. In order to have a perceptible and continuous discharge of fluid, the altitude of it in a reservoir, above plane of conduit pipe, must not be less than .082 ins. for every 100 feet of length of pipe.

4. In construction of hydraulic machines, it is not enough that elbows and contractions be avoided, but also any intermediate enlargements, the injurious effects of which are proportionate, as in following Table, for like volumes of fluid, under like heads in pipes, having a different number of enlarged parts.

No. of Parts.	Velocity.	No. of Parts.	Velocity.	No. of Parts.	Velocity.	No. of Parts.
0	1	1	.741	3	.569	5

* See D'Aubuisson, page 66.

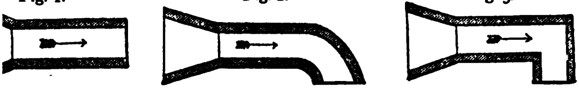
† Hutton

Friction.

ving of liquids through pipes or in natural channels is materially af- by friction.

qual volumes of water were to be discharged through pipes of equal :ers and lengths, but of following figures:

Fig. 1. Fig. 2. Fig. 3.



	Figs. 1.	2.	3.
e *times* would be as	1,	1.11, and	1.55.
ıd *velocities* as	1,	.72, and	.64.

ıcharges from Compound or Divided Reservoirs.

ocity in each may be considered as generated by difference of heights ıtiguous reservoirs; consequently, square root of difference will rep- velocities, which, if there are several apertures, must be inversely as espective areas.

ε.—When water flows into a vacuum, 32.166 feet must be added to height of l when into a rarefied space only, height due to difference of external and ıl pressure must be added.

VELOCITY OF WATER OR OF FLUIDS.

Coefficients of Discharge.

ficient of Discharge or *Efflux* is product of coefficients of *Contraction elocity.*

ascertained in practice that water issuing from a *Circular Aperture* ıin plate contracts its section at a distance of .5 its diameter from re to very nearly .8 diameter of aperture, so as to reduce its area to about .61.* Velocity at this point is also ascertained to be about mes theoretical velocity due to a body falling from a height equal d of water. Mean velocity *in aperture* is therefore .974, which, × .594, theoretical discharge; and in this case .594 becomes *coefficient of ·ge,* which, if expressed generally by C, will give for discharge itself

$\overline{g\,h} \times C = V$. *a representing area of aperture, and* V *volume discharged per* Or, $4.97\, a\sqrt{h} = V$. Or, $3.91\, d^2\sqrt{h} = V$. *d representing diameter in feet.*

e, for cube feet per second, $4.97\, a\sqrt{h}$, or $3.91\, d^2\sqrt{h}$.

ıTRATION.—Assume head of water 10 feet, diameter of opening 1.127 feet, ıq. foot, and C = .62.

$1\sqrt{2\,g\,10} \times .62 = 15.72$ *cube feet.* $4.97 \times 1 \times \sqrt{10} = 15.72$ *cube feet,* and $1.127^2 \times \sqrt{10} = 15.7$ *cube feet.*

ıquare aperture it is .615, and for rectangular .621.

ıme of water or a fluid discharged in a given time from an aperture iven area depends on head, form of aperture, and nature of approaches.

$\overline{h} = v^2$, and $\dfrac{v^2}{64.333} = h$. *h representing height to centre of opening in feet.*

ε.—*Head*, or *height*, *h*, may be measured from surface of water to centre of re without practical error, for it has been proved by Mr. Neville that for cir- pertures, having their centre at the depth of their radius below the surface, erefore *circumference touching* the surface, the error cannot exceed 4 per ' *excess of the true theoretical* discharge, and that for depths exceeding thre

---

61. Observed discharges of water coincide nearer to unit of Bayer than that of all oth

times the diameter, the error is practically immaterial. For rectangular apertures it is also shown that, when their upper side is at surface of the water, as in notches, the extreme error cannot exceed 4.17 per cent. in excess; and when the upper is three times depth of aperture below the surface, the excess is inappreciable.

For notches, weirs, slits, etc., however, it is usual to take full depth for head, when .666 only of above equation must be taken to ascertain the discharge.

Experiments show that *coefficient* for similar apertures in thin plates, for small apertures and low velocities, is greater than for large apertures and high velocities, and that for elongated and small apertures it is greater than for apertures which have a regular form, and which approximate to the circle.

When Discharge of a Fluid is under the Surface of another body of a like Fluid.—The difference of levels between the two surfaces must be taken as the head of the fluid.

$$\text{Or, } \sqrt{2\,g\,(h-h')}=v.$$

When Outer Side of opening of a discharging Vessel is pressed by a Force.—The difference of height of head of fluid and quotient of pressures on two sides of vessel, divided by density of fluid, must be taken as heads of fluid.

$$\text{Or, } \sqrt{2\,g\left(h-\frac{(p-p')\times 144}{S}\right)}=v. \quad S \textit{ representing density of fluid.}$$

Illustration.—Assume head of water in open reservoir is 12 feet above water-line in boiler, and pressures of atmosphere and steam are 14.7 and 19.7 lbs.

$$\text{Then } \sqrt{2\,g\left(12-\frac{(19.7-14.7)\times 144}{62.5}\right)}=\sqrt{64.333\times\left(12-\frac{5\times 144}{62.5}\right)}=5.56 \textit{ feet.}$$

When Water flows into a rarefied Space, as into Condenser of a Steam-engine, and is either pressed upon or open to Atmosphere.—The height due to mean pressure of atmosphere within condenser, added to height of water above internal surface of it, must be taken as head of the water.

$$\text{Or, } \sqrt{2\,g\,(h+h')}=v.$$

Illustration.—Assume head of water external to condenser of a steam-engine to be 3 feet, vacuum gauge to indicate a column of mercury of 26.467 ins. (=13 lbs.), and a column of water of 13 lbs. = 29.9 *feet.*

$$\text{Then } \sqrt{2\,g\,(3+29.9)}=\sqrt{64.333\times 32.9}=\sqrt{2116.57}=46 \textit{ feet.}$$

Relative Velocity of Discharge of Water through different Apertures and under like Heads.

Velocity that would result from direct, unretarded action of the column of water which produces it, being a constant, or	1
Through a cylindrical aperture in a thin plate	[illegible]
A tube from 2 to 3 diameters in length, projecting outward	[illegible]
A tube of the same length, projecting inward	[illegible]
A conical tube of form of contracted vein	[illegible]
Wide opening, bottom of which is on a level with that of reservoir; sluice with walls in a line with orifice; or bridge with pointed piers	[illegible]
Narrow opening, bottom of which is on a level with that of reservoir; abrupt projections and square piers of bridges	[illegible]
Sluice without side walls	[illegible]

Discharge or Efflux of Water for various Openings Apertures.

Rectangular Weir.

Weirs are designated *Perfect* when their sill is above surface of stream, and *Imperfect*, *Submerged*, or *Drowned* when it is below th

Height measured from Surface of Water to Sill. (*Jas. B. Francis.*)

Mean Head.	Length of Opening.	Mean Discharge per Second.	Mean Coefficient.
.62 to 1.55 feet.	10 feet.	32.9 cube feet.	.623

Principal causes for variation in coefficients derived from most experi-ents giving discharge of water over weirs arises from,

1. Depth being taken from only one part of surface, for it has been proved at heads *on, at, and above a weir* should be taken in order to determine ae discharge.

2. Nature of the approaches, including ratio of the water-way in channel ove, to water-way on weir.

When a weir extends from side to side of a channel, the contraction is s than when it forms a notch, or Poncelet weir, and coefficient sometimes es as high as .667.

When weir or notch extends only one fourth, or a less portion of width, fficient has been found to vary from .584 to .6.

When wing-boards are added at an angle of about 64°, coefficient is greater an even when head is less.

Computation of Volume of Discharge.

Mean velocity of a fluid issuing through a rectangular opening in le of a vessel is two thirds of that due to velocity at sill or lower ge of opening, or it is that due to a point four ninths of whole height m surface of fluid.

Height measured from Surface of Head of Water to Sill of Opening.

Rule.—Multiply square root of product of 64.333 and height or whole pth of the fluid in feet, by area in feet, and by *coefficient* for opening, and o thirds of product will give volume in cube feet per second.

Or, $\frac{2}{3} b\, h \sqrt{2\, gh}\, C = V$; $\quad \frac{V}{\frac{2}{3} b\, h \sqrt{2\, gh}\, C} = t$; and $\left(\frac{V}{\frac{2}{3} C\, b\, h}\right)^2 \div 2\, g = h$.

t representing time in seconds and V *volume in cube feet.*

Example.—Sill of a weir is 1 foot below surface of water, and its breadth is 10 t; what volume of water will it discharge in one second?

$C = .623$, $\sqrt{64.33 \times 1} \times \overline{10 \times 1} = 80.2$, and $\frac{2}{3}\, 80.2 \times .623 = 33.32$ *cube feet.*

Note.—Mean coefficient of discharge of weirs, breadth of which is no more than rd part of breadth of stream, is two thirds of $.6 = .4$; and for weirs which extend ole width of stream it is two thirds of $.666 = .444$.

Or, $214 \sqrt{h^3} = V$ *in cube feet per minute. When h is in ins., put* 5.15 *for* 214.

Or, $C\, b\, h \sqrt{2\, g\, h} = V$. C for a depth .1 of length $= .417$, and for .33 of length $= .4$.

Or, by formula of Jas. B. Francis: $3.33\, (L - .1\, n \cdot H)\, H^{\frac{3}{2}} = V$.

L representing length of weir and H *depth of water in canal, sufficiently far from ir to be unaffected by depression caused by the current, both in feet, and n number end contractions.*

Note.—When contraction exists at each end of weir. $n = 2$; and when weir is of th of canal or conduit, end contraction does not exist, and $n = 0$.

This formula is applicable only to rectangular and horizontal weirs in side of a m, vertical on water-side, with sharp edges to current; for if bevelled or rounded *in any perceptible degree, a material effect will be produced in the discharge essential also that the stream,* after passing the edges, should in nowise *icted in its flow and descent.*

In cases in which depth exceeds one third of length of weir, this form applicable. In the observations from which it was deduced, the depth v 7 to nearly 19 ins.

With end contraction, a distance from side of canal to weir equal t weir is least admissible, in order that formula may apply correctly.

Depth of water in canal should not be less than three times that on v curate computation of flow.

ILLUSTRATION.—If an overfull weir has a length of 7.94 feet and a de (as determined by a hook gauge), what volume will it discharge in 24 ho

$3.33\ (7.94 - .2 \times .986)\ .986^{\frac{3}{2}} = 3.33 \times \overline{7.94 - .1972} \times .979\,07 = 3.33$ $.979\,07 = 25.243\,875$, which $\times\,60 \times 60 \times 24 = 2\,181\,061$ *cube feet.*

By Logarithms.—Log. 3.33 $= .522\,444$

$7.7428 = .888\,898$

$.986^{\frac{3}{2}} = \bar{1}.993\,877$

$\times\ 3$

$2)\ \bar{1}.981\,631$

$\bar{1}.990\,815 = \bar{1}.990\,815$

$1.402\,157$

Log. 24 hours = 86 400 *seconds.* $4.936\,514$

$6.338\,671$

Log. $6.338\,67 = 2\,181\,073$ *cube feet.* C in this case = .615.

Or, $214\sqrt{H^3}$ and $5.15\sqrt{h^3} = V$, if stream above the sill is not in *representing height of surface of water above sill in feet, h in i* $214\sqrt{H^3 + .035\,v^2\,H^3} = V$, if in motion. *v representing velocity of a water in feet per second, and* V *volume in cube feet discharged over eac of sill per minute.*

In gauging, waste-board must have a thin edge. Height measured to face not affected by the current of overfall. (*Molesworth.*)

To Compute Depth of Flow over a Sill that w charge a given Volume of Water.

$\left(\dfrac{3\,V}{2\,C\,b\sqrt{2g}} + k^{\frac{3}{2}}\right)^{\frac{2}{3}} - k = d.$ $k = \dfrac{v^2}{2g}$ *representing height due to velo flows to the weir.*

NOTE.—When back-water is raised considerably, say 2 feet, velocity proaching weir (k) may be neglected.

Rectangular Notches, or Vertical Apertures or

A *Notch* is an opening, either vertical or oblique, in side of a ve voir, etc., alike to a narrow and deep weir.

Vertical Apertures or *Slits* are narrow notches or weirs, run near to bottom of vessel or reservoir.

Coefficient for opening, 8 ins. by 5, mean .606 (*Poncelet and Les*

Coefficient increases as depth decreases, or as ratio of length its depth increases.

When sides and under edge of a notch increase in thickness, so as to be into a short open channel, coefficients reduce considerably, and to an ext what increased resistance from friction, particularly for small depths, in

Poncelet and Lesbros found, for apertures 8 × 8 ins., that addition of a shoot 21 ins. long reduced coefficient from .604 to .601, with a head of ab but for a head of 4.5 ins. coefficient fell from .572 to .483.

For Rule and Formulas, see preceding page.

gular Openings or Sluices, or Horizontal Slits.

sured from Surface of Head of Water to Upper Side and to Sill of Opening.

ient for { Opening, 1 inch by 1 inch. Head, 7 to 23 feet. = .621.
" 3 " " 3 " " 7 " 23 " = .614.
" 2 feet " 1 foot. " 1 " 2 " = .641.

nd Lesbros deduced that coefficient of discharge increases with small long apertures as they approach the surface, and decreases with large apertures under like circumstances.

s ranged, in square apertures of 8 by 8 ins., under a head of 6 ins. to apertures, 8 by 4 ins.; under a head of 10 feet, from .572 to .745.

Plate, C = .616 (*Bossut*); C = .61 (*Michelotti*).

To Compute Discharge.

Multiply square root of 64.333 and breadth of opening in feet, by for opening, and by difference of products of heights of water and e roots, and two thirds of whole product will give discharge in er second.

$$\sqrt{2g}\,(h\sqrt{h}-h'\sqrt{h'})\,C = V; \qquad \frac{V}{\frac{2}{3}\,b\sqrt{2g}\,(h\sqrt{h}-h'\sqrt{h'})\,C} = t; \quad \text{and}$$

v. h and h' representing depth to sill and opening in feet, and v velocity cond.

—Sill of a rectangular sluice, 6 feet in width by 5 feet in depth, is 9 feet e of water; what is discharge in cube feet per second?

$$9-5=4, \text{ and } \frac{2}{3}\sqrt{2g}\times 6\times .625\times(9\sqrt{9}-4\times\sqrt{4}) = 380.95 \textit{ cube feet.}$$

$\overline{2gd}\,a\,C = V$. *d representing depth to centre of opening in feet.*

$$= 6.5, \quad a = 6\times 5 = 30, \text{ and } \sqrt{64.33\times 6.5}\times 30\times .625 = 383.44 \textit{ cube ft.}$$

Sluice Weirs or Sluices.

e of water by Sluices occurs under three forms—viz., *Unimpeded, Partly Unimpeded.*

Compute Discharge when Unimpeded.

$\overline{h} = V$. *d representing depth of opening and h taken from centre of rface of water.*

y, k, with which water flows to sluice is considered,

$$\Big)^2 - k = h; \qquad \frac{V}{C\,b\sqrt{2gh}} = d; \quad \text{and} \quad \frac{V}{C\,b\sqrt{2g\left(h'-\frac{d}{2}\right)}} = d.$$

ting height to which water is raised by dam above sill.

ION.—How high must the gate of a sluice weir be raised, to discharge t of water per second, its breadth being 24 feet and height, h', 5 feet?

riment = .6. d approximately = 1.

$$\frac{250}{.6\times 24\sqrt{64.33\left(5-\frac{1}{2}\right)}} = \frac{250}{14.4\times 17.014} = 1.0204 \textit{ feet.}$$

To Compute Discharge when Impeded.

$$C\,d\,b\sqrt{2gh} = V, \quad \text{and} \quad \frac{V}{C\,b\sqrt{2gh}} = d.$$

g difference of level between supply and back-water.

To Compute Discharge when partly Impeded.

$C b \sqrt{2g}\left(d\sqrt{h-\frac{d}{2}}+d'\sqrt{h}\right)=V.$ *d' representing depth of back-water above upper edge of sill.*

Illustration.—Dimensions of a sluice are 18 feet in breadth by .5 in depth, height of opening above surface of water .7 feet, and difference between levels of supply and surface water is 2 feet; what is discharge per second?

$$.6\times 18\times 8.02\left(.7\sqrt{2-\frac{.7}{2}}+.5\sqrt{2}\right)=86.62\times\overline{.896+.707}=138.85 \text{ cube feet.}$$

Coefficients of Circular Openings or Sluices.

Height measured from Surface of Head of Water to Centre of Opening.

Contraction of section from 1 to .633, and reduction of velocity to .974; hence $.633\times.974=.617$ (*Neville*).

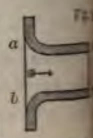
In a Thin Plate, C = .666 (*Bossut*); .631 (*Venturi*); .64 (*Eytelwein*).

Cylindrical Ajutages, or Additional Tubes, give a greater discharge than apertures in a thin side, head and area of opening being the same; but it is necessary that the flowing water should entirely fill mouth of ajutage.

Mean coefficient, as deduced by *Castel*, *Bossut*, and *Eytelwein*, is .82.

Short Tubes, Mouth-pieces, and Cylindrical Prolongations or Ajutages.

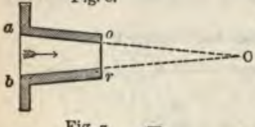
Fig. 4.



If an aperture be placed in side of a vessel of from 1.5 to 2.5 diameters in thickness, it is converted thereby into a short tube, and coefficient, instead of being reduced by increased friction, is increased from mean value up to about .815, when opening is cylindrical, as in Fig. 4; and when junction is rounded, as in Fig. 5, to form of contracted vein, coefficient increases to .958, .959, and .975 for heads of 1, 10, and 15 feet.

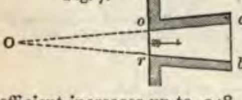
Conically Convergent and Divergent Tubes.

Fig. 6.



In conically divergent tube, Fig. 6, coefficient of discharge is greater than for same tube placed convergent, fluid filling in both cases, and the smaller diameters, or those at same distance from centres, O O, being used in the computations.

Fig. 7.



A tube, angle of convergence, O, of which is 5° nearly, with a head of from 1 to 3 feet, axial length of which is 3.5 ins., small diameter 1 inch, and large diameter 1.3 ins., gives, when placed as at Fig. 6, .921 for coefficient; but when placed as at Fig. 7, coefficient increases up to .948. Coefficient of velocity is, however, less for Fig. 6 than for Fig. 7, and discharging jet has greater amplitude in ... If a prismatic tube project beyond sides into a vessel, coefficient was reduced to .715 nearly.

Form of tube which gives greatest discharge is that of a truncated cone, lesser base being fitted to reservoir, Fig. 7. Venturi concluded th...

nents that tube of greatest discharge has a length 9 times diameter of r opening base, and a diverging angle of 5° 6′—discharge being 2.5 ter than that through a thin plate, 1.9 times greater than through a t cylindrical tube, and 1.46 greater than theoretic discharge.

Compound Mouth-pieces and Ajutages.

Fig. 8.

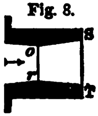


Fig. 9.

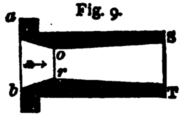
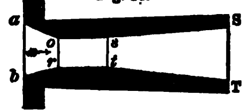


Fig. 10.



efficients for Mouth-pieces, Short Tubes, and Cylindrical Prolongations.

Computed and reduced by Mr. Neville, from Venturi's Experiments.

Description of Aperture, Mouth-piece, or Tube.	C. for Diam. $a\,b$.	C. for Diam. $o\,r$.
n aperture 1.5 ins. diameter, in a thin plate	.622	.974
ube 1.5 ins. diameter, and 4.5 ins. long, Fig. 4	.823	.823
ube, Fig. 5, having junction rounded to form of contracted vein	.611	.956
hort conical convergent mouth-piece, Fig. 6	.607	.934
ike tube divergent, with smaller diameter at junction with reservoir; length 3.5 ins., $o\,r = 1$ in., and $a\,b = 1.3$ ins.	.561	.948
ouble conical tube, $a\,o$, S T, $r\,b$, Fig. 9, when $a\,b =$ S T $= 1.5$ ins., $o\,r = 1.21$ ins., $a\,o = .92$ in., and o S $= 4.1$ ins.	.928	1.428
ike tube when, as in Fig. 8, $a\,o\,r\,b = o$ S T r, and $a\,o$ S $=$ 1.84 ins.	.823	1.266
ike tube when S T $= 1.46$ ins., and o S $= 2.17$ ins.	.823	1.266
ike tube when S T $= 3$ ins., and o S $= 9.5$ ins.	.911	1.4
ike tube when o S $= 6.5$ ins., and S T $= 1.92$ ins.	1.02	1.569
ike tube when S T $= 2.25$ ins., and o S $= 12.125$ ins.	1.215	1.855
tube, Fig. 10, when $o\,s = r\,t = 3$ ins., $o\,r = s\,t = 1.21$ ins., and tube o S T r, as in No. 6, S T $= 1.5$ ins., and s S $= 4.1$ ins.	.895	1.377

ean of various experiments with tubes of .5 to 3 ins. in diameter, and a head of fluid of from 3 to 20 feet, gave a coefficient of .813; and as n for circular apertures in a thin plate is .63, it follows that under lar circumstances, $.813 \div .63 = 1.29$ times as much fluid flows through be as through a like aperture in a thin plate.

receding Table gives coefficients of discharge for figures given, and it be found of great value, as coefficients are calculated for large as well mall diameters, and the necessity for taking into consideration form of tion of a pipe with a reservoir will be understood from the results.

Circular Sluices, etc.

To Compute Discharge.

ght measured from Surface of Head of Water to Centre of Opening.

ULE.—Multiply square root of product of 64.333 and depth of centre of ing from surface of water, by area of opening in square feet, and this uct by coefficient for the opening, and whole product will give discharge ube feet per *second*.

$\sqrt{2\,g\,d}\,a\,C = V$. *a representing area in sq. feet, and d depth of surface from centre of opening in feet.*

EXAMPLE.—Diameter of a circular sluice is 1 foot, and its centre is 1.5 feet b surface of the water; what is discharge in cube feet per second?

Area of 1 foot $= .7854$; $C = .64$, and $\sqrt{64.333 \times 1.5} \times .7854 \times .64 = 4.938$ *cube*

When Circumference reaches Surface of Water. $\sqrt{2\,g\,r}$, $.9604\,a\,C =$ *r representing radius of circle in feet.*

ILLUSTRATION.—In what time will 800 cube feet of water be discharged thro circular opening of .025 sq. foot, centre of which is 8 feet below surface of wate

$$C = .63. \quad \frac{800}{\sqrt{2\,g\,d} \times .025 \times .63} = \frac{800}{22.68 \times .025 \times .63} = 2239.58 = 37 \text{ min. } 19.6$$

NOTE.—For circular orifices, the formula $\sqrt{2\,g\,d}\,a\,C = V$ is sufficiently exac all depths exceeding 3 times diameter; the finish of openings being of more than extreme accuracy in coefficient.

Semicircular Sluices.

When Diameter is either Upward or Downward. $\sqrt{2\,g\,d}\,a\,C = V$. *d* re*senting depth of centre of gravity of figure from surface.*

When Diameter as above is at Depth d, below Surface. $\sqrt{2\,g\,d}\;1.188\,a\,C$:

Circular, Semicircular, Triangular, Trapezoidal, Pr matic Wedges, Sluices, Slits, etc.

See Neville, London, 1860, *pp.* 51–63, *and Weisbach, vol.* i. *p.* 456.

For greater number of apertures at any depth below surface of wa product of area, and velocity of depth of centre, or centre of grav if practicable to obtain it, will give discharge with sufficient accurac

Discharge from Vessels not Receiving any Supply

For prismatic vessels the general law applies, that twice as much wo be discharged from like apertures if the vessels were kept full during time which is required for emptying them.

To Compute Time. $\dfrac{2\,A\sqrt{h}}{C\,a\sqrt{2\,g}} = \dfrac{2\,A\,h}{V} = t.$

ILLUSTRATION.—A rectangular cistern has a transverse horizontal section of feet, a depth of 4 feet, and a circular opening in its bottom of 2 ins. in diameter; what time will it discharge its volume of water, when supply to it is cut off cistern allowed to be emptied of its contents?

$h = 4$ *feet*, $a = 2^2 \times .7854 \div 144 = .0218$, $C = .613$, and $\sqrt{2\,g\,h} \times a \times C = .2$ *cube foot per second.* Then $\dfrac{2 \times 14 \times 4}{.2143} = 522.6$ *seconds.*

To Compute Time and Fall.

...sion or subsidence of surface of water in a vessel, corresponding ...e of efflux, is $h - h'$. *h' representing lesser depth.*

$$\frac{A}{\sqrt{2g}}(\sqrt{h - h'}) = t. \qquad \text{Inversely, } \left(\sqrt{h} - \frac{C\,a\sqrt{2\,g}}{2\,A}\,t\right)^2 = h'.$$

In what time will the water in cistern, as given in precedi ...much will it subside in that time?

$\sqrt{2\,g} = 8.02$, $h = 4$, $h' = 4 - 1.6 = 2.4$.

$\sqrt{2.4}) = \dfrac{28}{.1049} \times (2 - 1.55) = 120.1$ seconds.

$)^2 = \overline{2 - .45} = 2.4$ feet; hence, $4 - 2.4 =$

Divide result obtained as precedi

ɔharge, when Form and Dimensions of Vessel of Efflux are not known.

lume discharged may be estimated by observing heads of the water at . intervals of time; and at end of half time of discharge, head of water ɔe .25 of whole height from surface to delivery.

en $t =$ *such interval. For openings in bottom or side,* $C\,a\,t\sqrt{2g}\left(\frac{\sqrt{h}+\sqrt{h_1}}{2}\right)$

for 1 *depth;* $C\,a\,t\sqrt{2g}\left(\frac{\sqrt{h}+4\sqrt{h_1}+\sqrt{h_2}}{3}\right) = V$ *for* 2 *depths;* and

$\sqrt{2g}\left(\frac{\sqrt{h}+4\sqrt{h_1}+2\sqrt{h_2}+4\sqrt{h_3}+\sqrt{h_4}}{3}\right) = V$ *for* 4 *depths.*

ᴇ.—At end of half time of discharge, head of water will be .25 of whole height surface to delivery.

Weirs or Notches.

$b\,t\sqrt{2g}\,(\sqrt{h^3}+4\sqrt{h^3_1}+\sqrt{h^3_2}) = V.$ *b representing breadth in feet.*

ɪsᴛʀᴀᴛɪᴏɴ.—A prismatic reservoir 9 feet in depth is discharged through a 2.222 feet wide, surface subsiding 6.75 feet in 935 seconds; what is volume ɪrged?

.6, $h_1 = 9 - 6.75 = 2.25$ *feet,* and $\frac{2}{9}$ .6 × 2.222 × 935 × 8.02 $(\sqrt{9^3}+4$ $\overline{3}+\sqrt{0^3}) = 2221.6 \times 40.5 = 89\,974.8$ *cube feet.*

When there is an Influx and Efflux.

ɪ reservoir during an efflux from it has an influx into it, determination ɪe in which surface of water rises or falls a certain height becomes so licated that an approximate determination is here alone essayed.

ate of permanency or constant height occurs whenever head of water is in- d or decreased by $\frac{1}{2g}\left(\frac{I}{C\,a}\right) = k.$ I *representing influx in cube feet per second.*

e (t) in which variable head (x) increases by volume (v) $= \frac{A_1\,v}{I - C\,a\sqrt{2gx}}$; me in which it sinks height, k, by $\frac{A_1\,v}{C\,a\sqrt{2gx} - I}$. Time of efflux, in which ing surface falls from A to A_1, etc., and head of water from h to h_1, when epresented by $\frac{I}{C\,a\sqrt{2g}} = \sqrt{k}$, is

$$\frac{\cdot h_4}{\sqrt{2g}}\left(\frac{A}{\sqrt{h}-\sqrt{k}}+\frac{4\,A_1}{\sqrt{h_1}-\sqrt{k}}+\frac{2\,A_2}{\sqrt{h_2}-\sqrt{k}}+\frac{4\,A_3}{\sqrt{h_3}-\sqrt{k}}+\frac{A_4}{\sqrt{h_4}-\sqrt{k}}\right) = t.$$

ˢᴛʀᴀᴛɪᴏɴ.—In what time will surface of water in a pond, as in a previous ɪle, fall 6 feet, if there is an influx into it of 3.0444 cube feet per second?

$$\sqrt{k} = \frac{3.044}{.537 \times .8836 \times 8.02} = .8. \quad C = .537 \text{ and } a = .8836.$$

$$\frac{20-14}{\cdot .537 \times .8836 \times 8.02} \times \left(\frac{600\,000}{4.472 - .8}+\frac{4 \times 495\,000}{4.301 - .8}+\frac{2 \times 410\,000}{4.123 - .8}+\frac{4 \times 325\,000}{3.937 - .8}\right.$$

$$\left.\frac{5000}{\cdot 2 - .8}\right) = \frac{6}{45.665} \times 1\,480\,201 = 194\,486 \textit{ seconds} = 54\ h.,\ 1\ min.,\ 26\ sec.$$

Prismatic Vessels.

essel has a uniform transverse section, A.

$$\frac{2\,A}{C\,a\sqrt{2g}}\left[\sqrt{h}-\sqrt{h_1}+\sqrt{k} \times \text{hyp. log.}\left(\frac{\sqrt{h}-\sqrt{k}}{\sqrt{h_1}-\sqrt{k}}\right)\right] = t = \text{tim}$$

vater flows from h to h_1.

ILLUSTRATION.—A reservoir has a surface of 500 000 sq. feet, a depth of 20 feet; it is fed by a stream affording a supply of 3.0444 cube feet per second, and outlet has an area of .8836 sq. foot; in what time will it subside 6 feet?

$\sqrt{k}$, as before, $=.8$, $C=.537$, and $\frac{2\times 500\,000}{C\,a\sqrt{2\,g}}\times\Big[\sqrt{20}-\sqrt{14}+.8\times$ hyp. log
$\left(\frac{\sqrt{20}-.8}{\sqrt{14}-.8}\right)\times 2.303\Big]=238\,414$ *seconds* $=66$ *h.* 13 *min.* 34 *sec.*

To Compute Fall in a given Time.

This is determining head h_1 at end of that time, and it should be subtracted from head h at commencement of discharge. Put into preceding equation several values of h_1, until one is found to meet the condition.

ILLUSTRATION.—Take a prismatic pond having a surface of 38 750 sq. feet, a depth to centre of opening of sluice of 10.5 feet, a supply of 33.6 cube feet, and a discharge of 40 cube feet per second.

$$\sqrt{k}=.84.$$

Putting these numerical values into the equation, and assuming different values for h_1, a value which nearly satisfies the equation is 4. Consequently, $10.5-4=6.5$ *feet, fall.*

$$\frac{A\,k}{3\,I}\left[\text{hyp. log.}\,\frac{h_1+\sqrt{h_1\,k}+k}{(\sqrt{h_1}-\sqrt{k})^2}+\sqrt{12}\text{ arc}\left(\text{tang.}=\frac{-\sqrt{3\,h_1}}{2\sqrt{k}+\sqrt{h_1}}\right)\right]=t;$$

$\left(\frac{I}{\frac{2}{3}\,C\,b\sqrt{2\,g}}\right)^{\frac{2}{3}}=k$; arc (tang. $=y$, *arc tangent of which* $=y$, *and* I *as preceding.*

According as k is $\lesseqgtr h$, and influx of water, $I\gtreqless\frac{2}{3}\,C\,l\sqrt{2\,g\,h^3}$, there is a rise or fall of fluid surface, the condition of permanency occurring when $h_1=k$, and time corresponding becomes ∞.

ILLUSTRATION.—In what time will water in a rectangular tank, 12 feet in length by 6 feet in breadth, rise from sill of a weir or notch, 6 inches broad, to 2 feet above it, when 5 cube feet of water flow into the tank per second?

$$h_1=2,\quad h=0,\quad A=12\times 6=72,\quad I=5,\quad b=.5,\quad C=.6.$$

$$k=\left(\frac{5}{\frac{2}{3}.6\times .5\times 8.02}\right)^{\frac{2}{3}}=\sqrt[3]{3.117^2}=2.1338.$$

Then $\frac{72\times 2.1338}{3\times 5}\Big[$hyp. logarithm $\frac{2+\sqrt{2\times 2.1338}+2.1338}{(\sqrt{2}-\sqrt{2.1338})^2}+\sqrt{12}$ arc $\Big($tang. $=$
$\frac{-\sqrt{3\times 2}}{2\sqrt{2.1338}+\sqrt{2}}\Big)\Big]=10.2423\times$ hyp. log. $\frac{6.1996}{.002\,162}-3.4641\times$ arc $\Big($tang. $\frac{\sqrt{6}}{4.335}\Big)=$
$10.2423\times[7.961-(3.461\times$ arc, tangent of which $=.56497$, or $29°\ 28'=$ 29.4..., length of which $=.5143)=1.781]=10.2423-7.961-1.781=10.2423\times 6.1...=$
63.297 *seconds.*

Discharge of Water under Variable Pressures.

To Compute Time, Rise and Fall, and Volume.

$\frac{a}{A}\sqrt{2\,g\,x}=v$. *x representing variable head, A and a areas of transverse horizontal section of vessel and discharge, and v theoretical velocity of efflux.*

To Compute Volume.

$A\,y=V$. *y representing extent of fall, and V volume of water discharged* $h-h'$.

ILLUSTRATION.—Assume elements of preceding case.

$A=14$. $\quad y=4$ *feet.* $\quad$ Then $56\times 4=224$ cube feet.

Discharge from Vessels of Communication.

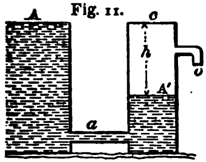
When Reservoir of Supply is maintained at a uniform Height.—Fig. 11.

To Compute Time. $\dfrac{2\,A\sqrt{h}}{C\,a\sqrt{2\,g}} = t.$

ILLUSTRATION 1.—In what time will level of water in a receiving vessel having a section of 14 sq. feet attain height of that in supply, through a pipe 2 ins. in diameter, placed 4 feet below level of supply?

$$C = .613. \quad \frac{2 \times 14 \times \sqrt{4}}{.613 \times .0218 \times 8.02} = \frac{56}{.1072} = 522.3 \textit{ seconds.}$$

Fig. 11.



2.—Assume C, vessel, Fig. 11, to be a cylinder 18 ins. in diameter, head of water in A = 4 feet, at A' 1 foot, and 2 feet below outlet o; in what time will water in vessel run out and over at o through a pipe, a, 1.5 ins. diameter?

$$h - h' = 4 - 1 - 2 = 1 \textit{ foot.} \qquad C = .8.$$

$$\frac{A}{a} = \left(\frac{18}{1.5}\right)^2 = 144.$$

Then $\dfrac{2 \times 144}{.8 \times 8.03}\,(\sqrt{3} - \sqrt{1}) = \dfrac{288}{6.424} \times \overline{1.73 - 1} = 32.73$ *seconds.*

When Vessel of Supply has no Influx, and is not indefinitely great compared with Receiving Vessel.

$\dfrac{2\,A\,A'\sqrt{h}}{C\,a\,(A + A')\sqrt{2\,g}} = t.$ *A' representing section of receiving vessel, t time in which the two surfaces of water attain same level; and* $\dfrac{2\,A\,A'(\sqrt{h} - \sqrt{h'})}{C\,a\,(A + A')\sqrt{2\,g}} = t$, *time within which level falls from h to h'.*

ILLUSTRATION.—Section of a cistern from which water is to be drawn is 10 sq. feet, and section of receiving cistern is 4 sq. feet; initial difference of level is 3 feet, and diameter of communicating pipe is 1 inch; in what time will surfaces of water in both vessels attain like levels?

$$C = .82. \qquad 1'' = .7854. \qquad \frac{2 \times 10 \times 4\sqrt{3}}{.82 \times .7854 \times \frac{14}{144} \times 8.02} = \frac{138.56}{.502} = 276 \textit{ seconds.}$$

Discharge from a Notch* in Side of a Vessel.

When it has no Influx. $\dfrac{3\,A}{C\,b \times \sqrt{2\,g}}\left(\dfrac{1}{\sqrt{h'}} - \dfrac{1}{\sqrt{h}}\right) = t.$ *b breadth of notch in feet.*

ILLUSTRATION.—If a reservoir of water, 110 feet in length by 40 in breadth, has a notch in end of 9 ins. in width; in what time will head of water of 15 ins. fall to 6?

$$C = .6. \qquad 9'' = .75 \textit{ foot.} \qquad h' = .5. \qquad h = 1.25.$$

$$\frac{3 \times 110 \times 40}{.6 \times .75 \times 8.02} \times \left(\frac{1}{\sqrt{.5}} - \frac{1}{\sqrt{1.25}}\right) = \frac{13\,200}{3.61} \times \overline{1.414 - .894} = 1901 \textit{ seconds.}$$

NOTE.—For discharge of vessels in motion, see Weisbach, vol. 1, pp. 394–396.

Reservoirs or Cisterns.

To Compute Time of Filling and of Emptying a Reservoir under Operation of both Supply and Discharge.

$\dfrac{V}{S - D} = T$, and $\dfrac{V}{D - S} = t.$ *V representing volume of vessel, S supply of and D discharge of water, both per minute, and in cube feet. T time of filling and t time of discharging it, both in minutes.*

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* When the notch extends to the bottom of the reservoir, etc., the time for the water … definite, as $h' = 0$.

Irregular-Shaped Vessels, as a Pond, Lake, etc.

To Compute Time and Volume Discharged.

Operation.—Divide whole mass of water into four or six strata of equal depths.

Then, *for 4 Strata*, $\frac{h-h^4}{12 C a \sqrt{2g}} \times \left(\frac{a}{\sqrt{h}} + \frac{4a^1}{\sqrt{h^1}} + \frac{2a^2}{\sqrt{h^2}} + \frac{4a^3}{\sqrt{h^3}} + \frac{a^4}{\sqrt{h^4}}\right) = t$; h, h^1, etc., *representing depths of strata at* a, a^1, etc., *commencing at surface;* a, a^1, etc., *being areas of first, second*, etc., *transverse sections of pond*, etc. : and $\frac{h-h^4}{12} \times a + 4a^1 + 2a^2 + 4a^3 + a^4 = V$.

Fig. 12.

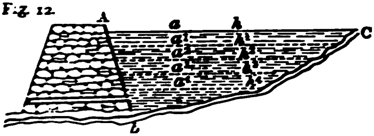


Illustration. — In what time will depth of water in a lake A b C, Fig. 12, subside 6 feet, surfaces of its strata having following areas, outline of sluice being a semicircle, 18 ins. wide, 9 deep, and 60 feet in length?

a	at 20	feet (h)	depth of water	=	area of	600 000	sq. feet.
a^1	" 18.5	" (h^1)	"	"	=	"	495 000	"
a^2	" 17	" (h^2)	"	"	=	"	410 000	"
a^3	" 15.5	" (h^3)	"	"	=	"	325 000	"
a^4	" 14	" (h^4)	"	"	=	"	265 000	"

a = area of $18 \div 2 = .8836$ *sq. feet;* C = .537.

Then $\frac{20-14}{12 \times .537 \times .8836 \times 8.02} \times \left(\frac{600\,000}{4.472} + \frac{4 \times 495\,000}{4.301} + \frac{2 \times 410\,000}{4.123} + \frac{4 \times 325\,000}{3.937} + \frac{265\,000}{3.742}\right) = \frac{6}{45.665} \times 1\,194\,431 = 156\,938$ *sec.* = 43 *h.*, 35 *min.* 38 *sec.*

And discharge $= \frac{6}{12} \times (600\,000 + 4 \times 495\,000 + 2 \times 410\,000 + 4 \times 325\,000 + 265\,000) = .5 \times 4\,965\,000 = 2\,482\,500$ *cube feet.*

For 6 Strata, put $2a^4$, instead of a^4, and $4a^5$ and a^6 additional, and divide by 18 instead of 12.

Flow of Water in Beds.

Flow of water in beds is either *Uniform* or *Variable*. It is uniform when mean velocity at all transverse sections is the same, and consequently when areas of sections are equal; it is variable when mean velocities, and therefore areas of sections, vary.

To Compute Fall of Flow.

$C\frac{lp}{a} \times \frac{v^2}{2g} = h$. C *representing coefficient of friction, l length of flow, p perimeter of sides and bottom of bed, and h fall in feet.*

Illustration.—A canal 2600 feet in length has breadths of 3 and 7 feet, a depth of 3 feet, with a flow of 40 cube feet per second; what is its fall?

C = as per table below .007 565; $p = \sqrt{3^2+2^2} \times 2 + 3 = 10.2$; $a = 15$; and $v = 40 \div 15 = 2.66$. Hence $.007\,565 \times \frac{2600 \times 10.2}{15} \times \frac{2.66^2}{64.33} = 1.47$ *feet.*

To Compute Velocity of Flow. $\sqrt{\frac{a}{C \times lp} 2gh} = v$.

[illegible] canal 5800 feet in length has breadths of 4 and 12 feet, a depth [illegible] hat is velocity and volume of flow?

[illegible] $\sqrt{5^2+4^2} \times 2 + 4 = 16.8$, and $a = 40$.

[illegible] $\times 3 = \sqrt{.0542 \times 193} = 3.23$ feet. [illegible]

ients of Friction of Flow of Water in Beds, as in Rivers, Canals, Streams, etc.

In Feet per Second.

C.	Velocity.	C.	Velocity.	C.	Velocity.	C.
.008 15	.7	.007 73	1.5	.007 59	5	.007 45
.007 97	.8	.007 69	2	.007 52	8	.007 44
.007 85	.9	.007 66	2.5	.007 51	10	.007 43
.007 78	1	.007 63	3	.007 49	12	.007 42

orms of Transverse Sections of Canals, etc.

nce or friction which bed of a stream, etc., opposes to flow of water, uence of its adhesion or viscosity, increases with surface of contact ed and water, and therefore with the perimeter of water profile, or rtion of transverse section which comprises the bed.

n of flow of water in a bed is inversely as area of it.

regular figures, that which has greatest number of sides has for a least perimeter; hence, for enclosed conduits, nearer its transfile approaches to a regular figure, less the coefficient of its friction; ntly, a circle has the profile which presents minimum of friction.

a canal is cut in earth or sand and not walled up, the slope of its ild not exceed 45°.

Variable Motion.

le motion of water in beds of rivers or streams may be reduced to niform motion when resistance of friction for an observed length an be taken as constant.

ompute Volume of Water flowing in a River.

$$\frac{\sqrt{2gh}}{-\frac{1}{A^2}+C\frac{lp}{A_1+A}\left(\frac{1}{A^2_1}+\frac{1}{A^2}\right)}=V.$$ *A and A_1 representing areas of upper and lower transverse sections of flow.*

ATION.—A stream having a mean perimeter of water profile of 40 feet for f 300 feet has a fall of 9.6 ins.; area of its upper section is 70 sq. feet, and r 60; what is volume of its discharge?

in C for velocity due to this case, $92.35\sqrt{\frac{70+60\times\frac{9.6}{12}}{40\times300}}=8.59$ *feet*, for which, see Table above, $=.007\,44$.

$$\frac{\sqrt{64.33\times(9.6\div12)}}{-\frac{1}{60^2}+.007\,44\,\frac{300\times40}{70+60}\left(\frac{1}{70^2}+\frac{1}{60^2}\right)}=\frac{7.174}{\sqrt{.000\,330\,89}}=394.6 \text{ cube feet};$$

velocity $=\frac{394.6\times2}{70+60}=6.07$ *feet*, C for which is .007 45.

FRICTION IN PIPES AND SEWERS.

n in flow of water through pipes, etc., of a uniform diameter is in it of pressure, and increases directly as length, very nearly as squar ty of flow, and inversely as diameter of pipe.

vooden pipes friction is 1.75 times greater than in metallic.

ccupied in flowing of an equal quantity of water through Pipes *equal lengths,* and with equal heads, is proportionally as follo

ht Line as 90, *in* a True Curve as 100, and in a Right Angle a

To Compute Head necessary to overcome Friction of Pipe. (*Weisbach.*)

$\left(.0144+\frac{.01746}{\sqrt{v}}\right)\times\frac{l}{d}\times\frac{v^2}{5.4}=h'$. *$h'$ representing head to overcome friction of flow in pipe, l length of pipe, and v velocity of water per second, all in feet, and d internal diameter of pipe in ins.*

Illustration.—Length of a conduit-pipe is 1000 feet, its diameter 3 ins., and the required velocity of its discharge 4 feet per second; what is required head of water to overcome friction of flow in pipe?

$$\left(.0144+\frac{.01746}{\sqrt{4}}\right)\times\frac{1000}{3}\times\frac{16}{5.4}=.02313\times 333.333\times 2.963=22.845\ \textit{feet}$$

Head here deduced is height necessary to overcome friction of water in pipe alone.

Whole or entire head or fall includes, in addition to above, height between surface of supply and centre of opening of pipe at its upper end. Consequently, it is whole height or vertical distance between supply and centre of outlet.

To Compute whole Head, or Height from Surface of Supply to Centre of Discharge.

$$\left(C\times\frac{l}{d}+1.5\right)\times\frac{v^2}{2g}=h.$$

1.5 is taken as a mean, and is coefficient of friction for interior orifice, or that of upper portion of pipe.

To obtain C *or coefficient.* $\left(.0144+\frac{.01746}{\sqrt{v}}\right)=C.$

For facilitating computation, following Table of coefficients of resistance is introduced, being a reduction of preceding formula:

Coefficients of Friction of Water.
In Pipes at Different Velocities.

V. Ft.	V. Ins.	C.	V. Ft.	V. Ins.	C.	V. Ft.	V. Ins.	C.	V. Ft.	V. Ins.	C.	V. Ft.	V. Ins.	C.
	4	.0443	2	8	.025	5		.0221	7	4	.0208	11	6	[illegible]
	8	.0356	3		.0244	5	4	.0219	7	8	.0206	12		[illegible]
1		.0317	3	4	.0239	5	8	.0217	8		.0205	12	6	[illegible]
1	4	.0294	3	8	.0234	6		.0215	8	6	.0204	13		[illegible]
1	8	.0278	4		.0231	6	4	.0213	9		.0202	14		[illegible]
2		.0266	4	4	.0227	6	8	.0211	10		.0199	15		[illegible]
2	4	.0257	4	8	.0224	7		.0209	11		.0196	16		[illegible]

Illustration 1.—Coefficient due to a velocity of 4 feet per second is .0231.

2.—Take elements of preceding case.

$$\left(.0231\times\frac{1000\times 12}{3}+1.5\right)\times\frac{4^2}{64.33}=93.9\times\frac{16}{64.33}=23.35\ \textit{feet.}$$

Note.—In preceding formula l was taken in feet, as the multiplier of 12 for the d was cancelled by taking 5.4 for $2g$, but in above formula it is necessary to restore this multiplier.

Radii of Curvatures.

When Pipes branch off from Mains, or when they are deflected at angles, radius of curvature should be proportionate to their diameter.

	Ins.	Ins.	Ins.	Ins.
Diameter	2 to 3	3 to 4	6	8
Radius	18	20	30	[illegible]

Curves and Bends.

Resistance or loss of head due to curves and bends, alike to that of friction increases as square of velocity; when, however, curves have a long radiu and bends are obtuse, the loss is small.

Curved Circular Pipe. (*Weisbach*). $\frac{a}{180} \times \left[.131 + 1.847 \left(\frac{d}{2r}\right)^{\frac{7}{2}}\right] \times \frac{v^2}{2g} = h.$

a representing angle of curve, d diameter of pipe, r radius of curve, and h heigh due to friction or resistance of curve, all in feet.

For facility of computations, following values of $.131 + 1.847 \left(\frac{d}{2r}\right)^{\frac{7}{2}}$ are intro duced.

Coefficients of Resistance.

In Curved Pipes with Section of a Circle.

$\frac{d}{2r}$											
.1	.131	.25	.145	.4	.206	.6	.44	.75	.806	.9	1.408
.15	.133	.3	.158	.45	.244	.65	.54	.8	.977	.95	1.674
.2	.138	.35	.178	.5	.294	.7	.661	.85	1.177	1	1.978

ILLUSTRATION.—If in a pipe 18 ins. in diameter and 1 mile in length there is right-angled curve of 5 feet radius, what additional head of flow should be given t attain velocity due to a head of 20 feet?

$a = 90°$, v for such a pipe and head $= 4$ feet per second; $18 = 1.5$ and $\frac{1.5}{2 \times}$ $= .15$, and .15 by table $= .133$.

$$\text{Hence, } \frac{90}{180} \times .133 \times \frac{4^2}{64.33} = .5 \times .133 \times \frac{16}{64.33} = .01653 \textit{ foot.}$$

NOTE.—If angle is greater than 90°, head should be proportionately increased.

Bent or Angular Circular Pipes.

Coefficient for angle of bend $= .9457 \sin.^2 x + 2.047 \sin.^4 x$. Hence,

x	10°	20°	30°	40°	45°	50°	55°	60°	65°	70°
C	.046	.139	.364	.74	.984	1.26	1.556	1.861	2.158	2.43

and $\frac{v^2}{2g} \times C = h$. *x representing half angle of bend.*

ILLUSTRATION.—Assume $v = 4$ *feet*, and angle $= 90°$; $x = \frac{90°}{2} = 45°$.

Then $\frac{4^2}{64.33} \times .984 = .2447$ *foot additional head required.*

In Valve Gates or Slide Valves.

In Rectangular Pipes.

r	1	.9	.8	.7	.6	.5	.4	.3	.2	.1
C	.0	.09	.39	.95	2.08	4.02	8.12	17.8	44.5	193

r = ratio of cross section.

In Cylindrical Pipes.

h	0	.125	.25	.375	.5	.625	.75	.875
r	1	.948	.856	.74	.609	.466	.315	.159
C	.0	.07	.26	.81	2.06	5.52	17	97.8

h = relative height of opening.

In a Throttle Valve. *In Cylindrical Pipes.*

A	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°
r	.913	.826	.741	.658	.577	.5	.426	.357	.293	.234	.134
C	.24	.52	.9	1.54	2.51	3.91	6.22	10.8	18.7	32.6	118

A = angle of position.

In a Clack or Trap Valve.

Angle of opening.....	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	[illegible]
C	90	62	42	30	20	14	9.5	6.6	4.6	3.2	2.3	[illegible]

In a Cock. *In Cylindrical Pipes.*

A	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°
r	.926	.85	.772	.692	.613	.535	.458	.385	.315	.25	.19	.137	[illegible]
C	.05	.29	.75	1.56	3.1	5.47	9.68	17.3	31.2	52.6	106	206	[illegible]

In a Conical Valve. $\left(1.645\,\frac{a}{a'}-1\right)^2=C.$ *a and a' = areas of pi[pe] and opening.*

In Imperfect Contractions. $\left(\frac{a}{c\,a'}-1\right)^2=C.$ *c = a factor, r[an]ging from .624 for* $\frac{a}{a'}=.1$ *to 1 for* $\frac{a}{a'}=1$, *being greater the greater the ratio.*

ILLUSTRATION.—If a slide valve is set in a cylindrical pipe 3 ins. in diameter [an]d 500 feet in length, is opened to .375 of diameter of pipe (hence, .625 diameter clo[sed]), what volume of water will it discharge under a head of 100 feet, coefficient of [en]trance of pipe assumed at .5?

C, *by table, p. 545, pipe being .625 closed* = 5.52. $\dfrac{\sqrt{2g}\,\sqrt{h}}{\sqrt{\left(1.5+C+c\frac{h\times n}{a}\right)}}=v.$

C = *from table, p. 544, for an assumed velocity of 11 feet 6 ins.* = .0195.

$$\text{Then }\frac{\sqrt{64.33}\times\sqrt{100}}{\sqrt{\left(1.5+5.52+.0195\,\frac{500\times 12}{3}\right)}}=\frac{8.03\times 10}{\sqrt{(7.02+39)}}=\frac{80.3}{6.78}=11.85\textit{ feet.}$$

Hence, area of 3 ins. = 7.07, and 7.07 × 12 × 11.85 = 1005.4 *cube feet per second.*

Valves. (*Conical, Spherical, or Flap.*)

Conical or Spherical Valve Puppet.

Height due to resistance or loss of head of water $=11\,\frac{v^2}{2g}$. *v represe[nting] velocity of water in full diameter of pipe or vessel.*

$\left(\frac{A}{A'\,C'}-1\right)^2=C.$ A and A' *representing transverse areas of vessel and of [the] opening, and* $\left(1.645\,\frac{A}{A'}-1\right)^2=C$ *of contraction in general.*

ILLUSTRATION.—If A' = .5 of vessel, $C=\left(1.645\times\frac{1}{.5}-1\right)^2=2.29^2=5.24$

Clack or Trap Valve.—C decreases with diameter of vessel.

ILLUSTRATION.—If a single-acting force-pump, 6 ins. in diameter, delivers at [each] stroke 5 cube feet of water in 4 seconds, diameter of valve seat 3.5 ins., and of [...] 4.5; what resistance has water in its passage, and what is loss of mechanical [...]

$a=.196.$ $\left(\frac{3.5}{6}\right)^2=.34$ ratio of *transverse area of opening.* $1-\left(\frac{4.5}{6}\right)^2=.44$ *of annular contraction* to transverse area of vessel.

Hence, $\frac{.34+.44}{2}=.39$ mean ratio, and coefficient of resistance corre[sponding] *thereto* $=\left(\frac{1.645}{.39}-1\right)^2=3.22^2=10.37.$ $\frac{5}{4\times.196}=6.37$ velocity per [second].

$= .63$ *height due to velocity.* Consequently, $10.37 \times .63 = 6.53$ *height due to* *nce of valve, and* $\frac{5}{4} \times 62.5 \times 6.53 = 510.15$ *lbs. mechanical effect lost.*

Discharge of Water in Pipes.

any Length and Head, and for Diameters from 1 Inch to 10 Feet. *In Cube Feet per Minute.* (*Beardmore.*)

Tab. No.	Diam. Ft.	Diam. Ins.	Tab. No.	Diam. Ft.	Diam. Ins.	Tab. No.	Diam. Ft.	Diam. Ins.	Tab. No.	Diam. Ft.	Diam. Ins.	Tab. No.
4.71		9	1 147.6	1	11	11 983	3	1	39 329	4	9	115 854
8.48		10	1 493.5	2		13 328	3	2	42 040	5		131 703
13.02		11	1 894.9	2	1	14 758	3	3	44 863	5	3	148 791
19.15	1		2 356	2	2	16 278	3	4	47 794	5	6	167 139
26.69	1	1	2 876.7	2	3	17 889	3	5	50 835	5	9	186 786
46.67	1	2	3 463.3	2	4	19 592	3	6	53 995	6		207 754
73.5	1	3	4 115.9	2	5	21 390	3	7	57 265	6	6	253 781
108.14	1	4	4 836.9	2	6	23 282	3	8	60 648	7		305 437
151.02	1	5	5 628.5	2	7	25 270	3	9	64 156	7	6	362 935
194.84	1	6	6 493.1	2	8	27 358	3	10	67 782	8		425 431
263.87	1	7	7 433	2	9	29 547	3	11	71 526	8	6	496 275
416.54	1	8	8 449	2	10	31 834	4		75 392	9		572 508
612.32	1	9	9 544	2	11	34 228	4	3	87 730	9	6	655 369
854.99	1	10	10 722	3		36 725	4	6	101 207	10		745 033

s Table is applicable to Sewers and Drains by taking same proportion ular numbers that area of cross-section of water in sewer or drain to whole area of sewer or drain.

mula upon which the table is constructed is, $2356\sqrt{\frac{h}{l} \times d^5} = V$ in *et per minute,* and $39.27\sqrt{\frac{h}{l} \times d^5} = V$ *in cube feet per second.* *h represent-* *ght of fall of water and d diameter of pipe and l length, all in feet.*

To Compute Discharge.

elwein.) $\sqrt{\frac{d^5 h}{l}}\, 4.71 = V$, and $\sqrt[5]{\frac{l V^2}{h}}\, .538 = d$. *d = diameter of pipe in* *length of pipe and h head of water, both in feet.*

wksley.) $\sqrt[5]{\frac{G^2 l}{h}}\, \frac{1}{15} = d$, and $\sqrt{\frac{15\, d^5 h}{l}} = G$. *G = number of Imperial* *s per hour, and l length of pipe in yards.*

ville.) $140\sqrt{r\,s} - 11\sqrt[3]{r\,s} = v$ *in feet per second.* *r =* [illegible] *, and s sine of the inclination or total fall divided by* [illegible]
$.124\, d^2 = V$, and $v\; 293.7286\, d^2 =$ *Imperial gallons per* [illegible] *=* [illegible] *e in feet.*

To Compute Volume discharge [illegible]

ien Length of Pipe, Height or Fall, and D[illegible]
vide tabular number, opposite to diameter [illegible]
of inclination, and quotient will give volume [illegible]
te.

AMPLE.—*A pipe has a diameter of 9 ins., and a* [illegible]
charge per minute under a head of 17.5 feet?

Tab. No. 9 ins. $= 1147.6$, *and* $\frac{1147.6}{\sqrt{\frac{1750}{17.5}}} =$ [illegible]

To Compute Diameter.

When Length, Head, and Volume are given. RULE.—Multiply discharge per minute by square root of ratio of inclination; take nearest corresponding number in Table, and opposite to it is diameter required.

EXAMPLE.—Take elements of preceding case.

$$69.67 \times \sqrt{\frac{4750}{17.5}} = 1147.61, \text{ and opposite to this is 9 } ins.$$

Or, $\sqrt[5]{\frac{v\ l}{1542\ h}} = d$ *in feet.* v *representing velocity in feet per second and* l *length in feet.*

To Compute Head.

When Length, Discharge, and Diameter are given. RULE.—Divide tabular number for diameter by discharge per minute, square quotient, and divide length of pipe by it; quotient will give head necessary to force given volume of water through pipe in one minute.

EXAMPLE.—Take elements of preceding cases.

$$\frac{1147.61}{69.67} = 16.47;\ 16.47^2 = 271.3;\ 4750 \div 271.2 = 17.5\ feet.$$

To Compute whole Head necessary to furnish requisite Discharge.

See Formula and Illustration, page 544.

To Compute Velocity.

When Volume and Diameter alone are given. RULE.—Divide volume when in feet per minute by area in feet, and quotient, divided by 60, will give velocity in feet per second.

EXAMPLE.—Take elements of preceding case.

$$\frac{69.67}{.75^2 \times .7854} \div 60 = 2.63\ feet.$$

When Volume is not given. RULE.—Multiply square root of product of height of pipe by diameter in feet, divided by length in feet, by 50, and product will give velocity in feet per second. (*Beardmore.*)

To Compute Inclination of a Pipe.

When Volume, Diameter, and Length are given. $\left(\frac{V}{2356}\right)^2 \frac{1}{d^5} = \frac{h}{l}$.

ILLUSTRATION.—Take elements of preceding case.

$\left(\frac{69.67}{2356}\right)^2 \times \frac{1}{.75^5} = .000874 \times 4.214 = .00368$, and $\frac{17.5}{4750} = .00368$, or $4750 \times .00368$ $= 17.49$ *feet head.*

To Compute Elements of Long Pipes.

$$\frac{r}{\times d^2} = 1.2732 \frac{V}{d^2} = v; \quad \left(1 + c + C\frac{l}{d}\right)\frac{v^2}{2g} = h; \quad \frac{\sqrt{2gh}}{\sqrt{1 + c + C\frac{l}{d}}} = v;$$

$$\sqrt{(1.505 \times d + c\,l)\frac{V^2}{h}} = d \text{ in ins.}$$

orm ... nly give an approximate dimension in consequence

C, as $v = \frac{4V}{3.1416 \times d^2}$.

eous Illustration, page 556.

To Compute Vertical Height of a Stream projected from Pipe of a Fire-engine or Pump.

RULE.—Ascertain velocity of stream by computing volume of water running or forced through opening in a second; then, by Rule in Gravitation, page 488, ascertain height to which stream would be elevated if wholly unobstructed, which multiply by a coefficient for particular case.

In great heights and with small apertures, coefficients should be reduced. In consequence of the varying elements and conditions of operation of fire-engines, it is difficult to assign a coefficient for them. Difference between actual discharge and that as computed by capacity and stroke of cylinder, as ascertained by Mr. Larned, 1859, was 18 per cent. = a coefficient of .82.

A steam fire-engine of the Portland Company, discharging a stream 1.125 ins. in diameter, through 100 feet 2.5 inch hose, gave a theoretical head, computed from actual discharge, of 225 feet, and stream vertically projected was 200 feet; hence coefficient in this case was .88.

EXAMPLE.—If a fire-engine discharges 14 cube feet of water vertically through a pipe .75 inch in diameter in one minute, how high will the water be projected?

$14 \times 1728 \div .4417$ area of pipe, $\div 12$ ins. in a foot, $\div 60$ seconds $= 76.07$ *feet* velocity; and as coefficient of such a stream = at .85, then $114.1 \times .85 = 96.98$ *feet.*

Or, $H - \frac{.0022\,H^2}{d} = h$. H *representing head at nozzle, and d height of jet, both in feet, and d diameter of nozzle in ins.* (*R. F. Hartford.*)

ILLUSTRATION.—Assume head of 110 feet and diameter of nozzle .75 inch.

$$110 - \frac{.0022 \times 110^2}{.75} = 110 - 35.5 = 74.5\ \textit{feet.}$$

NOTE.—The loss of head is greater with ring than with smooth nozzles. E. B. Weston, Am. Soc. C. E., puts the difference at $.000\,171\ v^2$.

The loss of head increases with the absolute height of the jet, and is less with an increase of its diameter. This loss increases nearly in ratio of square of height of jet, and varies nearly in inverse ratio to its diameter.

Cylindrical Ajutage.

Mean coefficient as determined by Mariotte and Bossut = .003 066 square of effective head for cylindrical ajutages; hence, for conical, alike to that of an engine pipe, coefficient ranges from .72 to .9, or a mean of .81.

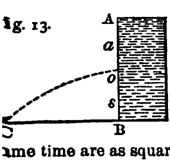
By formula of D'Aubuisson, $.003\,047\ h^2 = h'$.

Effective head, or h, in preceding example = 114.1. Then $114.1 - .003\,047 \times 114.1^2 = 114.1 - 39.67 = 74.43$ *feet height of jet.*

Hence, for a conical or engine pipe, $74.43 \times .81 = 60.29$ *feet*, or a coefficient of .535.

To Compute Distance a Jet of Water will be projected from a Vessel through an Opening in its Side.

Fig. 13.



B C, Fig. 13, is equal to twice square root of A $o \times o$ B.

If s is 4 times as deep below A as a is, s will discharge twice volume of water that will flow from a in same time, as 2 is $\sqrt{}$ of A s and 1 is $\sqrt{}$ of A a.

NOTE.—Water will spout farthest when o is equidistant from A and B; and if vessel is raised above a plane, B must be taken upon plane.

Volumes of water passing through equal apertures in same time are as square roots of their depths from surface.

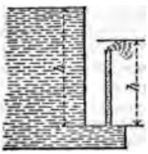
RULE.—Multiply square root of product of distance of opening from surface of water, and its height from plane upon which wat[illegible] feet by 2, and product will give distance in feet.

EXAMPLE.—A vessel 20 feet deep is raised 5 feet above a pl[illegible] which that is 5 feet from bottom of vessel?

$$20 - 5 \times \overline{5 + 5} = 150, \text{ and } \sqrt{150} \times 2 = 24.4[illegible]$$

Velocity of a jet of water flowing from a cylindrical tube is determined to be .974 to .98 of actual to theoretic velocity, or = .82 of that due to height of reservoir. Hence volume of discharge through a cylindrical opening $= .82\, a \sqrt{2\, g\, h}$.

Fig. 14.



Jets d'Eau. (Fig. 14.)

That a jet may ascend to greatest practicable height, communication with supply should be perfectly free.

Short tubes shaped alike to contracted fluid vein, and conically convergent pipes, are those which give greatest velocities of efflux. Hence, to attain greatest effect, as in fire-engines, long and slightly conically convergent tubes or pipes should be applied.

In order to diminish resistance of descending water, a jet must be directed with a slight inclination from vertical.

Effect of combined causes which diminish height of a jet from that due to elevation of its supply can only be determined by experiments. Great jets rise higher than small ones.

With cylindrical tubes, velocity being reduced in ratio of 1 to .82, and as heights of jets are as squares of these coefficients or ratios, or as 1 to .67, height of a jet through a cylindrical tube is two thirds that of head of water from which it flows.

$H\,C = h$. H *representing head of water*, C *coefficient, and h height of jet.* (*Molesworth.*)

When $d = H \div 300$, $C = .96$.	When $d = H \div 1500$, $C = .8$.
" " = " ÷ 450, " = .93.	" " = " ÷ 1800, " = .7.
" " = " ÷ 600, " = .9.	" " = " ÷ 2800, " = .6.
" " = " ÷ 800, " = .87.	" " = " ÷ 3500, " = .5.
" " = " ÷ 1000, " = .85.	" " = " ÷ 4500, " = .25.

FLOW OF WATER IN RIVERS, CANALS, AND STREAMS.

Running Water.—Water flows either in a natural or artificial bed or course. In first case it forms Streams, Brooks, and Rivers; in second, Drains, Cuts, and Canals.

Bed of a water-course is formed of a *Bottom* and two *Banks* or *Shores.*

Transverse Section is a vertical plane at right angles to course of the flowing water; *Perimeter* is length of this section in its bed.

Longitudinal Section or *Profile* is a vertical plane in the course or *thread of current* of flowing water.

Slope or *Declivity* is the mean angle of inclination of surface of the water to the horizon.

Fall is vertical distance of the two extreme points of a defined length of flowing course, measured upon a horizontal plane, and this fall assigns le for defined length of the course.

ine or *Thread of Current* is the point where flowing water attains its imum velocity.

-channel is deepest point of the bed in thread of current. *Velocity* is at surface and in middle of current; and surface of flowing water st in current, and lowest at banks or shore.

ver, Can is in a state of permanency when an equal quantity h of its transverse sections in an equal time, a section, and mean velocity through whole extent umber.

To Compute Mean Depth of Flowing Water.

Rule.—Set off breadth of the stream, etc., into any convenient number of ivisions; ascertain mean depths of these divisions; then divide their sum y number of divisions, and quotient is the mean depth.

To Compute Mean Area of Flowing Water.

Rule 1.—Multiply breadth or breadths of the stream, etc., by the mean epth or depths, and product is the area.

2.—Divide the volume flowing in cube feet per second by mean velocity ı feet per second, and quotient is area in sq. feet.

To Compute Volume of Flowing Water.

Rule.—Multiply area of the stream, etc., in sq. feet, by the mean velocity f its flow in feet, and product is volume in cube feet.

To Compute Mean Velocity of Flowing Water.

Rule.—Divide surface velocity of flow in feet per second by area of the tream, etc., and quotient, multiplied by coefficient of velocity, will give nean velocity in feet.

Mean velocity at half depth of a stream has been ascertained to be as .915 to 1, nd at bottom of it as .83 to 1, compared with velocity at surface. Again, the veocity diminishes from line of current toward banks, and, to obtain mean superficial elocity, $\frac{v_1+v_2+v_3}{n}=.915\,v$; hence,

To Compute Mean Velocity in whole Profile of a Navigable River, etc.,

$\overline{V+1}-2\sqrt{V}=$ *velocity at bottom*, and $\overline{V+.5}-\sqrt{V}=$ *mean velocity*.

In rivers of low velocities multiply mean velocity by .8.

Obstruction in Rivers. (*Molesworth.*)

$\frac{v^2}{58.6}+.05\times\left(\frac{A}{a}\right)^2-1=R$. *v representing velocity in ins. per second previous obstruction*, A *and a areas of river unobstructed and at obstruction in sq. feet, and ise in feet.*

Illustration.—Velocity of obstructed flow of a river is 6 feet per second, and as of section before and after obstruction are 100 and 90 sq. feet; what would be in feet?

$$\frac{6^2}{58.6}+.05\times\left(\frac{100}{90}\right)^2-1=.664\times.234=.155\,feet.$$

Flow of Water in Lined Channels. (*Bazin.*)

$\sqrt{\frac{C\,D}{F}}=V$; $\frac{1}{x\left(y+\frac{1}{D}\right)}=C$. D *representing mean hydraulic depth in feet*, F *fall, or length of channel to fall of* 1, *x and y as per table, and* C *as per table p.* 543.

	x	y		x	y
stered	.0000045	10.16	Rubble Masonry	.00006	1.219
Stone	.000013	4.354	Earth	.00035	.214

For Sections of Uniform Area, as Canals, Sewers, etc. $\sqrt{\frac{A}{P}\,2\,D}=v$. A = *a of flow in sq. feet*, P *wet perimeter of section, and* D *fall of stream per mile feet.*

Illustration.—Area of transverse section of a sewer is 50 sq. feet, its wet perimr 20 feet, and its fall 5 feet per mile.

$\sqrt{\left(\frac{50}{20}\times2\times5\right)}=\sqrt{25}=5\,feet.$ *For Sections of Rivers.* $12\sqrt{D\,\frac{A}{P}}=v$.

Illustration.—Assume area 500 sq. feet, wet perimeter 200, and fall 5 feet?

$$12\sqrt{5\times\frac{500}{200}}=12\sqrt{12.5}=42.4\,feet.$$

Hydraulic Radius or Mean Depth is obtained by dividing area of transverse section by wet perimeter, both in feet.

To Compute Fall per Mile for a required Mean Velocity.

$\left(\frac{v \times 12}{12}\right)^2 \div 2\,r = D.$ *r representing hydraulic radius in feet.*

Upper surface of flowing water is not exactly horizontal, as water at its surface flows with different velocities with respect to each other, and consequently exert on each other different pressures.

If v and v_1 are velocities at line of current and bank of a stream, the difference of the two levels is $\frac{v^2 - v_1^2}{2\,g} = h.$

ILLUSTRATION.—If $v = 5$ *feet*, and v_1 .9 v; then $\frac{5^2 - \overline{.9 \times 5}^2}{2\,g} = \frac{4.75}{64.33} = .0738$ *feet.*

A velocity of 7 to 8 ins. per second is necessary to prevent deposit of slime and growth of grass, and 15 ins. is necessary to prevent deposit of sand.

Maximum velocity of water in a canal should depend on character of bed of the channel.

Thus, *Mean Velocity* should not exceed per second over

Fine clay	6 ins.	River sand	1 ft.	Broken stones	[illegible]
A slimy bed	8 "	Small gravel	1 "	Stones	[illegible]
Common clay	6 "	Large shingle	3 "	Loose rocks	[illegible]

To Compute Velocity of Flow or Discharge of Water in Streams, Pipes, Canals, etc.

1. *When Volume discharged per Minute is given in Cube Feet, and Area of Canal, etc., in Sq. Feet.* RULE.—Divide volume by area, and quotient divided by 60, will give velocity in feet per second.

2. *When Volume is given in Cube Feet, and Area in Sq. Ins.* RULE.—Divide volume by area; multiply quotient by 144, and divide product by 60.

3. *When Volume is given in Cube Ins., and Area in Sq. Ins.* RULE.—Divide volume by area, and again by 12 and by 60.

To Compute Flow or Volume of Discharge.

1. *When Area is given in Sq. Feet.* RULE.—Multiply area of flow by its velocity in feet per second, and product, multiplied by 60, will give volume in cube feet per minute.

2. *When Area is given in Sq. Ins.* RULE.—Multiply area by its velocity and again by 60, and divide product by 144.

NOTE 1.—Velocities and discharges here deduced are theoretical, actual results depending upon coefficient of efflux used. Mean velocity, however, as before given, page 529, may be taken at $\sqrt{2\,g}\;.673 = 5.4$ feet, instead of 8.02 feet.

2.—As a rule, with large bodies, as vessels, etc., their floating velocity is somewhat greater than that of flow of water, not only because in floating they descend an inclined plane, formed by surface of the water, but because they are but slightly affected by the irregular intimate motion of water: the variation for small bodies is so slight that it may be neglected.

To Compute Height of Head of Flowing Water.

When Volume and Area of Flow are given in Feet. RULE.—Divide volume in feet per second by product of area, and $\frac{2}{3}$ coefficient for opening; square of quotient, divided by 64.33, will give height in feet.

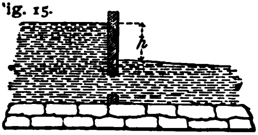
EXAMPLE.—Assume volume 266.48 cube feet, area 40 sq. feet, and C = .623.

Then $\left(\frac{266.48}{40 \times \frac{2}{3}.623}\right)^2 \div 64.33 = \frac{257.28}{64.33} = 4$ feet.

Submerged or Drowned Orifices and Weirs.

When wholly submerged (Fig. 15).—Available pressure at any point in depth of orifice is equal to difference of pressure on each side.

Fig. 15.



Whence, $C\sqrt{2gh}=v$, and $Ca\sqrt{2gh}=V$.

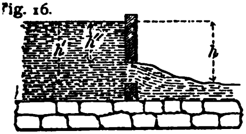
a representing area of sluice in sq. feet.

ILLUSTRATION.—Assume opening 3 feet by 5, $h=4$ feet, and $C=.5$.

Then, $.5\times\overline{3\times5}\ \sqrt{\overline{64.33\times4}}=7.5\times16.04=$ 120.3 *cube feet per second.*

When partly submerged (Fig. 16). $h'-h=d=$ submerged depth, and $h-h''=d'=$ remaining portion of depth; whence $d'+d=$ entire depth, and

Fig. 16.

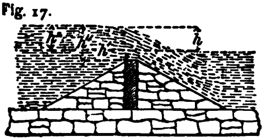


$$Cl\sqrt{2g}\,(d\sqrt{h}+\tfrac{2}{3}\,\overline{h\sqrt{h}-h''\sqrt{h''}})=V.$$

ILLUSTRATION.—Assume opening as above, $h=4$ *feet*, $h'=6$, $h''=3$, and $C=.5$. Then $d=6-4=2$ *feet.*

Then $.5\times5\times8.02\,(2\sqrt{4}+\tfrac{2}{3}\times\overline{4\sqrt{4}-3\sqrt{3}})$ $=20.05\times5.869=117.67$ *cube feet per second.*

Fig. 17.



When drowned (Fig. 17).

$$Cl\sqrt{2gh}\,(d+\tfrac{2}{3}h)=V.$$

ILLUSTRATION.—Assume opening as above, $h=4$ *feet*, $d=2$, and $C=.52$.

Then, $.52\times5\times\sqrt{\overline{64.33\times4}}\times(2+\tfrac{2}{3}\,4)=2.6$ $\times16.04\times4.66=194.34$ *cube feet per second.*

CANAL LOCKS.

Single Locks.

When a fluid passes from one level or reservoir to another, through an perture covered by the fluid in the latter, effective head on each point of perture, and consequently head due to velocity of efflux at each instant, is he difference of levels of the two reservoirs at that instant.

Hence $Ca\sqrt{2gh'}=V$ per second. *h' representing difference of levels.*

Co Compute Time of Filling and Discharging a Single Lock.—Fig. 18.

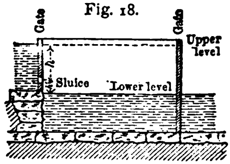
When Sluice in Upper Gate is entirely under Water, and above Lower Level.

$\dfrac{Ah'}{Ca\sqrt{2gh}}=$ *time of filling up to centre of sluice.*

h representing height of centre of sluice in upper ate from surface of canal or reservoir, and h' height f centre of sluice in upper gate from lower surace, or water in the lock or river, all in feet; and

$\dfrac{2Ah}{Ca\sqrt{2gh}}=$ *time of filling the remaining space, where a gradual diminution of head of water occurs.*

Fig. 18.



Consequently, $\dfrac{(h'+2h)A}{Ca\sqrt{2gh}}=t$ *time of filling a single lock.*

When Aperture or Sluice in Lower Gate is entirely under W

ver Level. $\dfrac{2A\sqrt{h+h'}}{Ca'\sqrt{2g}}=$ *time of emptying* or discharging it.

of lower sluice.

ILLUSTRATION.—Mean dimensions of a lock, Fig. 18, are 200 feet in length by 24 in breadth; height of centre of aperture of sluice from upper and lower surfaces 5 feet; breadth of both upper and lower sluices is 2.5 feet; height of upper is 4 feet, and of lower—entirely under water—5 feet; required the times of filling and discharging.

$h = 5$, $h' = 5$, $A = 200 \times 24 = 4800$, $C = .545$, $a = 4 \times 2.5 = 10$, $a' = 5 \times 2.5 = 12.5$

$\frac{4800 \times 5}{.545 \times 10 \times \sqrt{2gh}} = \frac{24\,000}{97.72} = 245.59$ *seconds = time of filling lock up to centre of sluice;* and $\frac{2 \times 4800 \times 5}{.545 \times 10 \times \sqrt{2gh}} = \frac{48\,000}{97.72} = 491.18$ *seconds = time of filling remaining space, or lock above centre of sluice,* and $245.59 + 491.18 = 736.77$ *seconds, whole time.*

Or, $\frac{(5 + \overline{2 \times 5}) \times 4800}{.545 \times 10 \times \sqrt{2gh}} = \frac{72\,000}{97.72} = 736.77$ *sec. = time of filling.* $\frac{2 \times 4800 \sqrt{5+5}}{.545 \times 12.5 \times \sqrt{2g}}$ $= \frac{30\,358.08}{54.7} = 554.9$ *seconds = time of discharging.*

When Aperture or Sluice in Upper Gate is entirely under Water and below Lower Level. $\frac{2A\sqrt{h-h'}}{Ca\sqrt{2g}}$ = *time of filling lock.*

When Sluice in the Lower Gate is in part above Surface of Lower Level and in part below it. $\frac{2A(h+h')}{Cb\sqrt{2g}\left(d\sqrt{h+h'-\frac{d}{2}}+d'\sqrt{h+h'}\right)}$ = *time of discharging. d and d' representing distances of part of aperture above and of below surface of lower water, b breadth of aperture, and h and h' as before.*

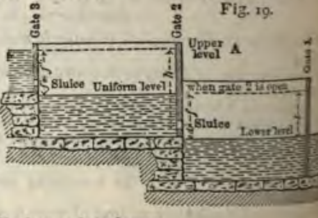
ILLUSTRATION.—Assume sluice in preceding example to be 1 foot above lower level of water, or that of lower canal; what is time of discharge of lock, distance of part of aperture 1 foot and of that below surface of water 4 feet?

$$\frac{2 \times 4800\,(5+5)}{.545 \times 2.5 \times 8.02\,[1 \times \sqrt{5+5-(1 \div 2)} + 4 \times \sqrt{5+5}]} = \frac{96\,000}{10.93 \times (3.082 + 12.65)} = \frac{96\,000}{171.95} = 558.3 \text{ seconds.}$$

Double Lock. *(J. D. Van Buren, Jr.)*

A double lock is not a duplication of a single lock in its operation, for its lower chamber supply of water is from upper one, having no influx, instead of a uniform supply flowing directly from surface level of canal or feeder.

Fig. 19.



Operation, therefore, of a double lock is complex, addition to formula for a single lock being that of discharging of water in upper lock to fill lower, the head of water gradually decreasing in the chamber, which is closed from upper reach during discharge into lower.

To Compute Time required for Water to Fall from Upper to Uniform Water Level.

1. $\frac{A}{Ca\sqrt{g}}(\sqrt{f} + \sqrt{2h} - \sqrt{2h - 2d}) = t$. A representing horizontal area of lock, and a area of sluice opening, both in sq. feet, C coefficient of discharge = ... openings with square arrises, g acceleration of gravity, f depth of centre

below uniform level, h depth of centre sluice opening below upper water level, and height of centre of sluice above lower water level, all in feet, and t time for water to fall from upper to uniform water level, in seconds.

ILLUSTRATION.—$A = 2000$ *sq. feet;* $C = .545$; $a = 5$; $f = 6$; $h = 14$; and $d =$ 2 *feet.* (Fig. 19.)

Then, $\frac{2000}{.545 \times 5 \times 5.67} = \frac{2000}{15.45} \times \overline{7.74 - 4.9} = 367.6$ *seconds.*

2. If $d = 0$; $\frac{A\sqrt{f}}{C\,a\sqrt{g}} = t$; $= \frac{2000 \times \sqrt{8}}{.545 \times 5 \times 5.67} = \frac{5660}{15.45} = 366.34$ *seconds.*

NOTE.—f is never greater than l (lift in feet); it is equal to l when $d = 0$; f_2 equal to l when $f_1 = 0$, never greater. In each case it is the unbalanced head above sluice, however far below the lowest water level the sluice is.

To Fill Upper Lock or Empty Lower.

To fill upper lock or empty lower, when the sluice is below the lowest water-line in either case, takes the same time; for the head diminishes at the same rate, one from the upper surface, the other from the bottom.

3. $\frac{A\sqrt{2f}}{C\,a\sqrt{g}} = t.$ Here, *f being below lowest water level of lock* $= 8$ *feet,* as $d =$

and f = whole lift $= \frac{2000\sqrt{2 \times 8}}{.545 \times 5 \times 5.67} = \frac{8000}{15.45} = 517.8$ *seconds.*

To Discharge a like Volume under a Constant Head.

4. $\frac{A\sqrt{f}}{C\,a\sqrt{2g}} = \frac{A}{C\,a}\sqrt{\frac{f}{2g}} = t. \quad = \frac{2000}{.545 \times 5}\sqrt{\frac{8}{64.33}} = 258.9$ *seconds,*

Or, one half the time given by preceding case.

The times deduced by preceding formulas are in the following proportions in order, as $1 : \sqrt{2} : \frac{\sqrt{2}}{2}$, or $1 : \sqrt{2} : \frac{1}{\sqrt{2}}$.

If sluice of upper lock, through which it is filled, is above lowest water level, then, by combining formulas 3 and 4, the time is thus deduced.

To fill from Lowest Water Level of said Lock to Level of Centre of Sluice.

5. $\frac{A\sqrt{f'}}{C\,a\sqrt{2g}} = t'.$ *f' representing height of centre of sluice above said lowest water level.*

To fill remaining Portion of Lock above Sluice.

6. $\frac{2A\sqrt{f''}}{C\,a\sqrt{2g}} = t''.$ *f'' representing depth below upper water level of centre of sluice or remaining portion of lift.* Hence, $t' + t'' = \frac{A}{C\,a\sqrt{2g}}(\sqrt{f'} + 2\sqrt{f''}) =$

To fill Lower Lock under Constant Head from Upper Canal Level.

7. $\frac{A\sqrt{h}}{C\,a\sqrt{2g}}\left(2 + \frac{d}{h} - \frac{2\sqrt{h-f}}{\sqrt{h}}\right) = t.$

8. If both lifts are the same, $h - f = l$, and $\frac{A\sqrt{h}}{C\,a\sqrt{2g}}\left(2 + \frac{d}{h} - 2\sqrt{\frac{l}{12}}\right.$

If lower lock is filled from upper one under a constant head, when lo... *down to lowest level, formula* 7 will apply by making $h = f$, and

$\frac{A}{C\,a\sqrt{2g}}\left(2\sqrt{f} + \frac{d}{\sqrt{f}}\right)$, which is identical with 7, for $f = f_2$ and $d = .$ *being the same.*

What volume will a pipe 48 feet in length and 2 ins. in diameter, under a head 'eet, deliver per second? (*Formula page* 547.)

bular number for diameter 2 ins., page 547, $= 26.69$.

$$\sqrt{\frac{48}{5}} = 3.1. \quad \text{Then } \frac{26.69}{3.1} = 8.61, \text{ which} \div 60 = .143 \textit{ cube feet.}$$

:his pipe had 5 curves of 90°, with radii $\frac{d}{2r} = \frac{2}{4} = .5$; what would be its dis- ;e per second?

$= .143$; $a = 2 \div 144 = .0139$; C *per table* $= \frac{d}{2r} = .294$; $v = \frac{.143}{.0139} = 10.29$ *feet.*

en $.294 \times \frac{90^\circ}{180^\circ} \times \frac{10.29^2}{64.33} = .147 \times 1.64 = .241$, *which* $\times$ 5 *for* 5 *curves* $= 1.2 =$ *t due to resistance of curves.* $h = 5 - 1.2 = 3.8$.

nce, if $\sqrt{2g\,5} = .143$; $\sqrt{2g\,3.8} = .125$ *cube feet.*

If a slide stop valve, set in a cylindrical conduit 500 feet in length and 3 ins. in eter, is raised so as to close .625 of conduit; what volume will it discharge r a head of 4 feet? (*Formula page* 546.)

'or conduit $= .5$, *for friction* .025, *and for slide valve* .375 *open, table, page* 545, $d = .25$, and $a = 7.07$ *sq. ins.*

$$\text{en } \frac{2gh}{\sqrt{\left(1 + .5 + 5.52 + .025\,\frac{500}{.25}\right)}} = \frac{16.06}{\sqrt{(7.02 + 50)}} = 2.13 \textit{ feet velocity, } \text{and}$$

$\times 12 \times 7.07 = 180.71$ *cube ins.*

If a single lock chamber is 200 feet in length by 24 in breadth, with a depth feet, centre of upper gate, which is 4 feet in depth by 2.5 in breadth, is at lle of depth of chamber, lower gate, 5 feet in depth by 2.5 in breadth and wholly ersed; what is time required for filling and discharging it? (*Formula p.* 553.)

$= .615$, $h = 5$, $h' = 5$, $A = 200 \times 24 = 4800$, $a = 4 \times 2.5 = 10$, and $a' = 5$ $5 = 12.5$

$$\frac{(2 \times 5 + 5)\,4800}{.615 \times 10\sqrt{64.33 \times 5}} = \frac{72\,000}{110.27} = 652.8 \textit{ seconds time of filling.}$$

$$\frac{2 \times 4800 \times \sqrt{5+5}}{.615 \times 12.5\,\sqrt{2g}} = \frac{30\,336}{61.73} = 491.4 \textit{ seconds time of emptying.}$$

In a moderately direct and uniform course of a river, the depths and velocities s follows; what is the volume of its flow and what its mean velocity? (*p.* 551.)

	Feet.	Feet.	Feet.	Feet.	Feet.
nces..........	5	12	20	15	7
hs	3	6	11	8	4
velocity......	1.9	2.3	2.8	2.4	2.1

Area of profiles $= 5 \times 3 + 12 \times 6 + 20 \times 11 + 15 \times 8 + 7 \times 4 = 455$ *sq. feet.*

$\times 1.9 + 72 \times 2.3 + 220 \times 2.8 + 120 \times 2.4 + 28 \times 2.1 = 1156.9$ *cube feet volume,*

$\frac{1156.9}{455} = 2.54$ *feet velocity.*

Miner's Inch.

"Miner's inch" is a measure for flow of water, and is an opening one square through a plank two inches in thickness, under a head of six s of water to upper edge of opening.

will discharge 11.625 U. S. gallons water in one minute

Theoretical IP under different Heads.

s in *feet.*	100	90	80	70	60	50	40	30	20	1
er IP...	3.25	3.61	4.06	4.64	5.41	6.5	8.12	10.8	16.2	2

ter Inch (Pouce d'eau).—Circular opening of 1 inch i *o a discharge of* 19.1953 cube meters per 24 hours.

HYDRODYNAMICS.

Hydrodynamics treats of the force of action of Liquids o
Fluids, and it embraces *Hydraulics* and *Hydrostatics:* the
which treats of liquids in motion, as flow of water in pipes
latter of pressure, weight, and equilibrium of liquids in a sta

Fluids are of two kinds, aeriform and liquid, or elastic and
and they press equally in all directions, and any pressure com
to a fluid at rest is equally transmitted throughout the whole

Pressure of a fluid at any depth is as depth or vertical h
pressure upon bottom of a containing vessel is as base and pe
lar height, whatever may be the figure of vessel. Pressure,
of a fluid, *upon any surface*, whether *Vertical*, *Oblique*, or *Hor*
equal to weight of a column of the fluid, base of which is equ
face pressed, and height equal to distance of centre of gravi
face pressed, below surface of the fluid.

Side of any vessel sustains a pressure equal to its area, mul
half depth of fluid, and whole pressure upon bottom and aga
of a cubical vessel is equal to three times weight of fluid.

Pressure upon a number of surfaces is ascertained by m
sum of surfaces into depth of their common centre of gravi
surface of fluid.

When a body is partly or wholly immersed in a fluid, verti
ure of the fluid tends to raise the body with a force equal to
fluid displaced; hence weight of any quantity of a fluid displa
buoyant body equals weight of that body.

Centre of Pressure is that point of a surface against which
presses, to which, if a force equal to whole pressure were a
wou[illegible] surface at rest. Hence distance of centre of pre
[illegible]rface from surface of fluid is same as *Centre of P*

Centres of Pressure.

[illegible], *Side, Base, Tangent, or Vertex of Figure at Surface of F*
[illegible]uring downward) that joins centres of two horizontal sid

[illegible]*e uppermost*, is at centre of a line raised from lower apex
[illegible]re of base; and *Vertex uppermost*, it is at .75 of a line le
[illegible]ning it with centre of base.

[illegible] *Triangle, Base uppermost*, is at intersection of a line exte
[illegible] to extremity of triangle by a line running horizontally fr
[illegible]ngle. *Vertex or Extremity uppermost*, is at intersection of
[illegible]he centre of the base to the vertex, by a line running horizon
[illegible]f triangle, measured from base.

[illegible], *either of parallel Sides at Surface*, $\frac{b+3b'}{2b+4b'} \times a = d$. *b an*
[illegible]*idths of figure, d distance from surface of fluid, and a length of*
[illegible]*sides*

[illegible] 1.25 of its radius, measured from upper edge.

[illegible], *Diameter at* [illegible] *fluid*, $\frac{3pr}{16} = d$. r representing ra

[illegible] $\frac{r-32r}{p-16} = d$.

ɘ, Base, or Tangent of Figure below Surface of Fluid.

ıngle or Parallelog'm. $\frac{2}{3} \times \frac{h'^3 - h^3}{h'^2 - h^2} = d$; or, $\frac{3\,m\,o + m^2}{3\,o} = d$; and $\frac{m^2}{3\,o} = d''$.

d h' representing depths of upper and lower surfaces of figure and d depth, om surface of fluid, m half depth of figure, o depth of centre of gravity of from surface of fluid, d' distance from upper side of figure, and d'' distance entre of gravity.

ngle.—Vertex Uppermost. $\frac{l^2 + 18\,o^2}{18\,o} = d$; $\frac{l^2}{18\,o} = d'$. *Base Uppermost.*

$\frac{o^2}{} = d.$ *l representing depth of figure, d distance from surface of fluid upon 'rom vertex to centre of base, and d' distance from centre of gravity of figure.*

'e. $\frac{4\,o^2 + r^2}{4\,o} = d$, or $\frac{r^2}{4\,o} =$ *distance from centre of circle.*

circle.—Diam. Horizontal and Upward or Downward. $\frac{l^2}{4\,o} - \frac{16\,l^2}{9\,p\,o} + o = d$;

$\frac{4\,l}{} = d'$; $\frac{4\,l}{3\,p} = d''$, and $\frac{l^2}{4\,o} - \frac{16\,l^2}{9\,p\,o} = c$. *d representing distance from of fluid, d' distance of centre of gravity from centre of arc, d'' distance of of gravity from diameter when it is uppermost, and c centre of pressure.*

Pressure.

;ompute Pressure of a Fluid upon Bottom of its Containing Vessel.

ɪᴇ.—Multiply area of base by height of fluid in feet, and product by ; of a cube foot of fluid.

;ompute Pressure of a Fluid upon a Vertical, Inclined, Curved, or any Surface.

ᴇ.—Multiply area of surface by height of centre of gravity of fluid , and product by weight of a cube foot of fluid.

ɪᴘʟᴇ 1.—What is pressure upon a sloping side of a pond of fresh water 10 feet and 8 feet in depth?

:e of gravity, $8 \div 2 = 4$ *feet from surface.* Then $10^2 \times 4 \times 62.5 = 25\,000$ *lbs.*

That is pressure upon staves of a cylindrical reservoir when filled with fresh lepth being 6 feet, and diameter of base 5 feet?

.1416 = 15.708 *feet curved surface of reservoir*, which is considered as a plane.

$$15.708 \times 6 \times \overline{6 \div 2} = 282.744, \text{ which } \times 62.5 = 17\,671.5 \text{ lbs.}$$

ɩ rectangular flood-gate in fresh water is 25 feet in length by 12 feet deep; ; pressure upon it?

$$25 \times 12 \times \overline{12 \div 2} = 1800, \text{ which } \times 62.5 = 112\,500 \text{ lbs.}$$

ın water presses against both sides of a plane surface, there arises from nt forces, corresponding to the two sides, a new resultant, which is ɜd by subtraction of former, as they are opposed to each other.

ɪᴛʀᴀᴛɪᴏɴ -Depth of water in a canal is 7 feet; in its adjoining lock it is 4 ɪd breadtn of gates is 15 feet; what mean pressure have they to sustain, and ı depth of point of its application below surface?

$5 = 105$, and $4 \times 15 = 60$ *sq. feet.* $(105 \times \frac{7}{2} - \overline{60 \times 2}) \times 62.5 =$ 1!

ressure.

$15468.75 \div 62.5 = 247.5 =$ *cube feet pressing upon gates upon h*

$\cdot 15 \times 7 = 2.35$ *feet = depth of centre of gravity of mean pressure*

To Compute Pressure on a Sluice.

$= P$, *and* $C\,P = P'$. *A representing area of sluice in sq. feet, cube foot, d mean depth of sluice below surface, in feet, P pressu ᴡᴇʀ required to operate it, both in lbs.*

$C = .68$ when sluice is of wood, and .31 when of iron.

EXAMPLE.—What is pressure on a sluice-gate 3 feet square, its centre of gra[illegible] being 30 feet below surface of a pond of fresh water?

$$3 \times 3 \times 30 = 270, \text{ which } \times 62.5 = 16\,875 \textit{ lbs.}$$

To Compute Pressure of a Column of a Fluid pe[r] Sq. Inch.

RULE.—Multiply height of column in feet by weight of a cube foot [of] fluid, and divide product by 144; quotient will give weight or pressure [per] sq. inch in lbs.

NOTE.—When height is given in ins., omit division by 144.

PIPES.

To Compute required Thickness of a Pipe.

RULE.—Multiply pressure in lbs. per sq. inch by diameter of pipe in i[ns.] and divide product by twice assumed tensile resistance or *value* of a [sq.] inch of material of which pipe is constructed.

By experiment, it has been found that a cast-iron pipe 15 ins. in diameter, [and] .75 of an inch thick, will support a head of water of 600 feet; and that one of [oak] of same diameter, and 2 ins. thick, will support a head of 180 feet?

EXAMPLE 1.—Pressure upon a cast-iron pipe 15 ins. in diameter is 300 lbs. per [sq.] inch; what is required thickness of metal?

$$300 \times 15 = 4500, \text{ which } \div \overline{3000 \times 2} = .75 \textit{ inch.}$$

NOTE.—Here 3000 is taken as *value* of tensile strength of cast iron in ordina[ry] small water-pipes. This is in consequence of liability of such castings to be im[-] perfect from honey-combs, springing of core, etc.

2.—Pressure upon a lead pipe 1 inch in diameter is 150 lbs. per sq. inch; what [is] required thickness of metal?

Here 500 is taken as *value* of tensile strength.

$$150 \times 1 = 150, \text{ which } \div \overline{500 \times 2} = .15 \textit{ inch.}$$

Cast-iron Pipes.

To Compute Thickness, etc., of Flanged Pipes.

For 75 lbs. Pressure.	*For 100 lbs. Pressure.*
$.025\,D + .25 = T$	$.03\,D + .3 = T$
[illegible] $D + .3 = t$	$.035\,D + .45 = t$
$D + 1.15 = l$	$.05\,D + 1.15 = l$
$D + .35 = f$	$.04\,D + .6 = f$
$D + \overline{4.25\,d} + 1.25 = o$	$1.1\,D + \overline{5 \times d} + 1.5 = o$
$D + \overline{2 \times d} + 1 = o'$	$1.1\,D + \overline{2.5 \times d} + 1.4 = o'$

$$.7\,D + 2.2 = n; \qquad \frac{A \times p \div n}{4000} = a, \text{ and } \sqrt{\frac{a}{.7854}} + C = d.$$

[D rep]*resenting diam. of pipe,* T *thickness of metal, t thickness and l length of bo[ss, f thick]ness of flange, o diam. of flange, o' diam. of centres at bolt holes, and d dia[m. of bolt], all in ins.; A area of pipe and a area of bolt at base of its thread, in sq. ins., [p pres]sure in lbs. per sq. inch, and C a coefficient due to diam. of bolt.*

[Bolt]s, diam. $.125 + .032$, $.25 + .064$, $.5 + .107$, $1 + .16$, $1.5 + .214$, and $2 + .285$.

[IL]LUSTRATION.—What should be dimensions of a flanged pipe, 10 ins. in diameter, [for a] pressure of 100 lbs. per sq. inch?

[.7] $\times 10 + 2.2 = 9.2 = 10$ *number of bolts*, and *diam.* 10 *ins.* $= 78.54$ *ins. area* $=$ [A].

[78].54 $\times$ [illegible] $= .196\,35$, and $\sqrt{\frac{.196\,35}{.7854}} + C = \sqrt{.25} = .5$; hence, $.5 + .107 =$ [illegible]

[illegible]: $.03 \times 10 + .3 = .6 =$ thickness of metal; $.035 \times 10$ [illegible]

$.05 \times 10 + 1.15 = 1.65 =$ length of boss; $.04 \times$ [illegible]

$.1 \times 10 + \overline{5 \times .625} + 1.5 = 15.625 =$ di[ameter] [illegible]

[illegible] $+ 1.4 =$ [illegible] $=$ diameter of bolt holes.

To Compute Elements of Water-pipes.

$245\,P\,d + C = t$; or, $.000054\,H\,d + C = t$; $.4336\,H = P$; and $\times 2.45 = W$. P *representing pressure of water in lbs. per sq. inch,* D *and d and internal diameters of pipe, and t thickness of metal, all in ins.,* C *coeffi- diameter of pipe, and* H *head of water in feet.*

.7 for pipes less than 12 ins. in diameter, .5 from 12 to 30, and .6 from 30 to 50.

To Compute Weight of Pipes.

diameter add thickness of metal, multiply sum by 10 times thickness, duct will give weight in lbs. per foot of length.

ght of Faucet end is equal to 8 ins. of length of pipe.

Hydrostatic Press.

o Compute Elements of a Hydrostatic Press.

$= W$; $\frac{W\,l'\,a}{P\,l} = A$; $\frac{W\,l'\,a}{l\,A} = P$; $\frac{P\,A\,l}{W\,l'} = a$. P *representing power or press- lied,* W *weight or resistance in lbs., l and l' lengths of lever and fulcrum in eet, and* A *and a areas of ram and piston in sq. ins.*

TRATION.—Areas of a ram and piston are 86.6 and 1 sq. ins., lengths of lever rum 4 feet and 9 ins., and power applied 20 lbs.; what is weight that may ined?

$$\frac{20 \times \overline{4 \times 12} \times 86.6}{9 \times 1} = \frac{83\,136}{9} = 9237.3 \text{ lbs.}$$

Compute Thickness of Metal to Resist a given Pressure.

E.—Multiply pressure per sq. inch in lbs. by diameter of cylinder in d divide product by twice estimated tensile resistance or *value* of n lbs. per sq. inch, and quotient will give thickness of metal required.

PLE.—Pressure required is 9000 lbs. per sq. inch, and diameter of cylinder is ; what is required thickness of metal of cast iron?

of metal is taken at 6000. $\frac{9000 \times 5.3}{6000 \times 2} = \frac{47\,700}{12\,000} = 3.975$ *ins.*

Values of Different Metals in Tons. (*Molesworth.*)

n...... .41 | Gun metal..... .22 | Wrought iron.. .14 | Steel......... .06

Hydraulic Ram.

ul effect of an Hydraulic Ram, as determined by Eytelwein, varied 9 to .18 of power expended. When height to which water is raised red to fall is low, effect is greater than with any other machine; but nishes as height increases.

th of supply pipe should not be less than .75 of height to which is to be raised, or 5 times height of supply; it may be much longer.

To Compute Elements.

$3\,V\,h = IP$; $\frac{881\,IP}{h} = V$; $1.45\sqrt{V} = D$; $.75\sqrt{V} = d$; a

y. V *and v representing volumes expended and raised, in , h and h' heights from which water is drawn and elevated i rs of supply and discharging pipes in ins., and* IP *effective ho*

STRATION.—Heights of a fall and of elevation are 10 and 26 *xpended and raised per minute are* 1.71 and .543 cube feet.

$\times 1.71 \times 10 = .0193\,IP$; $\frac{881 \times .0193}{10} = 1.71$ cube feet; 1..

$\sqrt{1.71} = .975$ *ins.*; and $\frac{5}{6} \times \frac{.543 \times 26.3}{1.71 \times 10} = .696$ efficiency.

WATER-WHEELS.

WHEELS are divided into two classes, Vertical and Horizontal. ›omprises *Overshot*, *Breast*, and *Undershot;* and Horizontal, *'mpact*, or *Reaction* wheels.

l wheels are limited by construction to falls of less than 60 feet. ıre applicable to falls of any height from 1 foot upward.

l wheels applied to a fall of from 20 to 40 feet give a greater ı a Turbine, and for very low falls Turbines give a greater effect.

ıs.—Methods of admitting water to an Overshot or Breast ꞉ various, consisting of *Overfall*, *Guide-bucket*, and *Penstock*.

ıll Sluice is a saddle-beam with a curved surface, so as to direct the water tangentially to buckets; a *Guide-bucket* is an apron by which ded in a course tangential to buckets; and a *Penstock* is sluice-board or as close to wheel as practicable, and of such thickness at its lower edge a contraction of current. Bottom surface of penstock is formed with a ɔ.

.ding of a wheel consists of plates at its periphery, which ıides of the bucket.

fall of a water-wheel is measured between surfaces of water in *penstock 'ace*, and, ordinarily, two thirds of height between level of reservoir and ich water strikes a wheel is lost for all effective operation.

ɔf a wheel at centre of percussion of fluid should be from .5 to .6 that ıe water.

fect in a fall of water is expressed by product of its weight t of its fall.

ıtio of Effective Power of Water Motors.

ıd high	from .68 to .6 to 1		Undershot, Poncelet's,	from	.6 to .4 to 1
			Undershot...........	"	.27 to .45 to 1
....	"	.6 to .8 to 1	Impact and Reaction............	"	.3 to .5 to 1
....	"	.45 to .65 to 1			
Ram......	"	.6 to 1	Water-pressure engine	"	.8 to 1

Overshot-wheel.

OT-WHEEL.—The flow of water acts in some degree by impact, y by its weight.

he speed of wheel at its circumference, the greater will be mechan- of the water, in some cases rising to 80 per cent.; with velocities to 6.5 feet, efficiency ranges from 70 to 75 per cent. Proper ve- ›out 5 feet per second.

of buckets should be as great, and should retain water as long, as ꞉. Maximum effect is attained when the buckets are so numerous :hat water surface in the bucket commencing to be empt ontact with the under side of the bucket next above ›s 12 ins. apart.

buckets give greatest effect, and Radial give but .78 ꞉kets. Wheel 40 feet in diameter should have 152 buck

heels give a less effect than large, in consequence of th l action, and discharging water from the buckets at n *with larger wheels*, or when their velocity is lower.

ad of water bears to fall or height of wheel a proportion *5, ratio of effect to* power is reduced. The general law *ratio of effect to* power decreases as proportion of head to *l increases.*

Wheel with shallow *Shrouding* acts more efficiently than on deep, and depth is usually made 10 or 12 ins., but in some case increased to 15.

Breadth of a wheel depends upon capacity necessary to give to receive required volume of water.

Form of Buckets.—Radial buckets—that is, when the bottom is a volve so great a loss of mechanical effect as to render their use inco economy; and when a bucket is formed of two pieces, lower or i termed *bottom* or *floor*, and outer piece *arm* or *wrist.* Former is usu a line with radius of wheel.

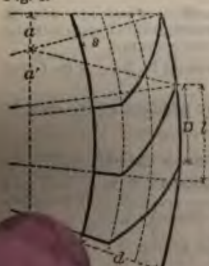
Line of a circle passing through *elbow*, made by junction of *floo* termed division circle, or *bucket pitch*, and it is usual to put this at o of shrouding.

When *arm* of a bucket is included in division angle of buckets, th

representing number of buckets, the cells are not sufficiently covered, e shallow shrouding; hence it is best to extend arm of a bucket over angle, so as to cover or overlap *elbow* of bucket next in advance of it.

Construction of Buckets (Fig. 1).—Capacity of bucket should be 3 of water.

Fig. 1.



Fairbairn gives area of opening of a wheel of great diameter, compared to the as 5 to 24.

Buckets having a bottom of two planes, two bottoms, and two division circles or b and an arm, give a greater effect than wit

When an opening is made in base of b to afford an escape of air contained with loss of water admitted, the buckets are *tilated*, and effective power of wheel is n than with closed buckets.

D = distance apart at periphery = d, shrouding, s length of radial start = .33 bucket curve = 1.25 d in large wheels, an under 25 feet, a angle of radius of curv with radial line of wheel at points of b (*Molesworth.*)

pute Radius and Revolutions of an O wheel, and Height of Fall of Water.

whole Fall and Velocity of Flow, etc., are given.

$= n$, $\quad \frac{v^2}{2g} 1.1 = h'$, and $\frac{3.1416\, n\, r}{h} = c$. *h representing hei*

height between the centre of gravity of discharge and half de ich water flows, v velocity of flow in feet per second, a angle w e of water into a bucket makes with summit of wheel, n number inute, v velocity of wheel at its circumference per second, and r its

—Height of whole fall is distance between surface of water at which lower buckets are emptied of water, and as a proportio w is lost, it is proper to assume height h' as above given.

ILLUSTRATION.—A fall of … 30 feet, velocity of its flow is 16 fee … 12°, and required velocity of wheel … what is requ… number of revolutions, and height …

$h' = \frac{16^2}{2g} \times 1.1$ … $= .978;\ \frac{30 - 4.38}{1 + .978} = \frac{25.62}{1.978} =$

$\frac{30 \times n}{3.1416 \times}$ … tions.

n Number of Revolutions and Ratio between Velocities of Flow (Circumference of Wheel are given.

$$\frac{\sqrt{.000772\,(x\,n)^2 h+(1+\cos.\,a)^2}-1+\cos.\,a)}{.000386\,(x\,n)^2}=r,\ x=\frac{v}{c},\ \text{and}\ \frac{3.1416\,n\,r}{30}=$$

USTRATION.—If number of revolutions are 5, $x=2$, and fall, etc., as in pre what is radius of wheel, velocity of flow, and height of fall?

$$\frac{\sqrt{.000772\ (2\times5)^2\times30+(1.978)^2}-1.978}{.000386\ (2\times5)^2}=\frac{.518}{.0386}=13.41\ \textit{feet.}$$

$\frac{416\times5\times13.41}{30}=7.03$ *feet.* Hence $7.03\times2=14.06$ *velocity of flow*, and $\frac{14}{64}$ $=3.38$ *feet.*

To Compute Width of an Overshot-wheel.

$;=w$. C *representing a coefficient* $=3$, *when buckets are filled to an excess, a*

n they are deficiently filled, V *volume of water in cube feet per second, s dep rouding, w width of buckets, both in feet, and c′ velocity of wheel at centre c ding, in feet per second.*

USTRATION.—A wheel is to be 31 feet in diameter, with a depth of shrouding o t, and is required to make 5 revolutions per minute under a discharge of 1(feet of water per second; what should be width of buckets?

sume $C=4$, and $c'=\frac{\overline{31-1}\times3.1416\times5}{60}=7.854$. Then $\frac{4\times10}{1\times7.854}$ 5.09 *feet.*

To Compute Number of Buckets.

$1+\frac{s}{.83}\Big)\div12=d$, and $\frac{D\,p\,s}{d}=n$. D *representing diameter of wheel, d dis- between centres of buckets, in feet, and n number of buckets.*

USTRATION.—Take elements of preceding case.

$17\left(1+\frac{1}{.83}\right)=7\times2.2\div12=1.283$, and $\frac{\overline{31-1}\times3.1416\times1}{1\ 283}=73.4$, say 72

; hence $\frac{360^{\circ}}{72}=5^{\circ}$, *angle of subdivision of buckets.*

To Compute Effect of an Overshot-wheel.

$$\frac{'-\left(\frac{v'^2}{2\,g}\mathrm{V}\,w+f\right)}{\mathrm{V}\,h\,w}=\mathrm{P}.$$ *w representing weight of cube foot of water in lbs., y of it discharged at tail of wheel, in feet per second,* V *volume of flow in and f friction of wheel in lbs.*

ATION.—A volume of 12 cube feet per second has a fall of 10 feet, wheel 8.5 feet of it, and velocity of water discharged is 9 feet per second; what fall?

of wheel is assumed to be 750 *lbs.*

$$\frac{\times62.5-\left(\frac{9^2}{64.33}\times12\times62.5+750\right)}{12\times10\times62.5}=\frac{6375-(1.26\times750+750)}{7500}\ .460.$$

of effect to power; and 4680×60 *seconds* $\div33\,000=8.51$ IP

Compute Power of an Overshot-whe

Multiply weight of water in lbs. discharged upon w eight or distance in feet from centre of opening in race; *divide product* by 33 000, and multiply qu *termined ratio* of effect to power. Or, for gener. *by 50 000, and* quotient is IP.

$h=$ IP, and $\frac{11.7}{h}=$ V *per second*; or, $\frac{771\ \text{IP}}{h}=$ V per min.

Poncelet's Wheel.

ONCELET'S WHEEL.—Buckets are curved, so that flow of water is in se of their concave side, pressing upon them without impact; and effect ·eater than when water impinges at nearly right angles to a plane sur- or blade.

iis wheel is advantageous for application to falls under 6 feet, as its t is greater than that of other undershot wheels with a curb, and for from 3 to 6 feet its effect is equal to that of a Turbine.

ır falls of 4 feet and less, efficiency is 65 per cent., for 4.25 to 5 feet, 60 :ent., and from 6 to 6.5 feet, 55 to 50 per cent.

its arrangement, aperture of sluice should be brought close to face of :l. First part of course should be inclined from 4° to 6°; remainder of se, which should cover or embrace at least three buckets, should be car- concentric to wheel, and at end of it a quick fall of 6 ins. made, to guard nst effect of back-water. Sluice should not be opened over 1 foot in any , and 6 ins. is a suitable height for falls of 5 and 6 feet.

istance between two buckets should not exceed 8 or 10 ins., and radius heel should not be less than 40 ins., or more than 8 feet.

ane of stream or head of water should meet periphery of wheel at an e of from 24° to 30°. Space between wheel and its *curb* should not ex- .4 of an inch.

epth of shrouding should be at least .25 depth of head of water, or such) prevent water from flowing through it and over the buckets, and width heel should be equal to that of stream of impinging water.

fect of this wheel increases with depth of water flow, and, therefore, r elements being equal, as filling of buckets, to obtain maximum effect, r should flow to buckets without impact, and velocity of wheel should ıly a little less than half that of velocity of water flowing upon wheel.

To Compute Proportions of a Poncelet Wheel.

TE.—As it is impracticable to arrive at the results by a direct formula, they be obtained by gradual approximation.

AMPLE.—Height of fall is 4.5 feet; volume of water 40 cube feet per second; s of wheel $= 2\,h$, or 9 feet; depth of the stream $= .75$ *feet;* and C assumed at .9.

epresenting volume of water in cube feet per second, h height of fall, d depth of ding $= \frac{1}{4} \cdot \frac{v^2}{2\,g} + d'$; *d' opening of and e width of sluice, r radius of curva- f buckets* $= \frac{d}{\cos. z}$, *and a of wheel, all in feet; n number of revolutions* $= \frac{30\,c}{p\,a}$ *inute; c velocity of circumference of wheel and v velocity of water, b... econd; C coefficient of resistance of flow of water; x angle betwee ng water and that of circumference of wheel at point of contact ̄. z; z angle made by circumference of wheel with end of bucket angle of direction of water from* circumference of wheel $= \frac{p\,c}{2\,a}$

$v = .9\sqrt{2\,g\left(h - \frac{d'}{2}\right)} = .9 \times 16.29 = 14.66$ *feet* ∴ velocity of

h *Breast-wheel* is used when level of water in *tail-race* and *penstock* ebay are subject to variation of heights, as wheel revolves in direction ich water flows from blades, and *back-water* is therefore less disad- geous, added to which, penstocks can be so constructed as to admit of ustable point of opening for the water to flow upon the wheel.

ct of this wheel is equal to that of the overshot, and in some instances, he advantageous manner in which water is admitted to it, it is greater both wheels have same general proportions.

ler circumstances of a variable supply of water, *Breast-wheel* is better ed for effective duty than *Overshot*, as it can be made of a greater ter; whereby it affords an increased facility for reception of water s buckets, also for its discharge at bottom; and further, its buckets easily overcome retardation of back-water, enabling it to be worked onger period in back-water consequent upon a flood.

well-constructed wheel an efficiency of 93 per cent. was observed by M. and Sir Wm. Fairbairn gives, at a velocity of circumference of wheel of an efficiency of 75 per cent. Velocity usually adopted by him was from 4 et per second, both for high and low falls; a minimum of 3.5 feet for a fall of a maximum of 7 feet for a fall of 5 to 6 feet.

n water flows at from 10° to 12° above horizontal centre of wheel, Fairbairn rea of opening of buckets, compared with their volume, as 8 to 24.

capacity between two buckets or blades should be very nearly double that of of water expended.

ompute Proportions and Effect of a Breast-wheel.

STRATION.—Flow of water is 15 cube feet per second; height of fall, measured entre of pressure of opening to tail-race, is 8.5 feet; velocity of circumference el 5 feet per second; and depth of buckets or blades 1 foot, filled to .5 of their e.

h of wheel $= \frac{V}{s\,d}$, *d representing depth, and v velocity of buckets;* $\frac{15}{1 \times 5} = 3$; buckets are but .5 filled, $3 \div .5 = 6$ *feet.* Assume water is to flow with double y of circumference of wheel; $v = 5 \times 2 = 10$ *feet;* and fall required to gen- his velocity $= \frac{v^2}{2\,g} \times 1.1 = h' = \frac{100}{64.33} \times 1.1 = 1.71$ *feet.*

icting this height from total fall, there remains for height of curb or shroud- fall during which weight of water alone acts, $h - h' = 8.5 - 1.71 = 6.79$ *feet.*

ing radius of wheel 12 feet, and radius of bucket circle 11 feet, whole mechan- ect of flow of water $= 15 \times 62.5 \times 8.5 = 7968.75$ *lbs.*, from which is to be de- from 10 to 15 per cent. for loss of water by escape.

retical effect, as determined by M. Morin, velocity of circumference about nat of water, and within velocities of 1.66 to 6 feet.

$\frac{\cos.\ a - v)\ v}{g} + h''\Big)$ V 62.5. *a representing angle of direction of velocity with water flows to wheel at centre of thread of flow and direction of velocity of it this line, and h″ h — h′ in feet.*

here assumed at 20°. See Weisbach, London, 1848, vol. ii. page 197, and for essarily small value of *a*, its cosine may be taken at 1. Cos. 20° —

$$\left(\frac{(10 \times .94 - 5)\ 5}{32.16} + 6.79\right) \times 15 \times 62.5 = 7.474 \times 15 \times 62.5 = 70$$

e reduced by a coefficient of .77 for a penstock sluice, and .

oretical effect, as determined by Weisbach, 7273 lbs.. *leducted losses, which* he computes as follows:

s by escape of water between wheel and curb............

by escape at sides of wheel and curb..................

tion and resistance of water = 2.5 per cent...............

Flutter-wheel.

r or Saw-mill Wheel—Is a small, low breast-wheel operating under head of water; the design of its construction, water being plenty, is inment of a simple application to high-speed connections, as a gang lar saw. In effect it is from .6 to .7 that of an overshot-wheel of d of fall.

$$\frac{V s}{150}(v - s) = \text{IP}. \quad \textit{v and s as preceding.}$$

Friction of Journals or Gudgeons.

ry considerable portion of mechanical effect of a wheel is lost in ef- orbed by friction of its gudgeons.

Compute Friction of Journals or Gudgeons of a Water-wheel.

C .0086 $= f$. W *representing weight of wheel in lbs.*, r *radius of gudgeon in* *n number of revolutions of wheel per minute.*

ell-turned surfaces and good bearings, C = .075 with oil or tallow; when il is well supplied = .054; and, as in ordinary circumstances, when a black- uent is alone applied = .11.

RATION.—A wheel weighing 25 000 lbs. has gudgeons 6 ins. in diameter, and revolutions per minute; what is loss of effect?

Assume C = .08. Then $25000 \times \frac{6}{2} \times 6 \times .08 \times .0086 = 309.6$ *lbs.*

ghts.—*Iron wheels* of 18 to 20 feet in diameter will weigh from 800 to per IP.

wheels of 30 feet in diameter, 2000 to 2500 lbs. per IP.

ompute Diameter and Journals of a Shaft, Stress laid uniformly along its Length.

ron, $\frac{\sqrt[3]{W l}}{9.6} = d$. *Wood*, $6.12\sqrt[3]{\frac{\text{IP}}{4}} = d$. W *representing weight or load in* *ngth of shaft between journals in feet, and d diameter of shaft in its body*

als or *Gudgeons.—Cast Iron*, $.048\sqrt{\frac{W}{2}} = d$.

Shaft has to resist both Lateral and Torsional Stress.—Ascertain neter for each stress, and cube root of sum of their cubes will give r.

To Compute Dimensions of Arms.

ron, $\frac{1.7\,d}{\sqrt[3]{n}} = w$. *d representing diameter of shaft, and w width of arm, both* *n number of arms*, $\frac{w}{5} = t$, *and t thickness of arm.*

Arm is of Oak, *w* should be 1.4 times that of iron, and thickness .7 that .

Memoranda.

ime of water of 17.5 cube feet per second, with a fall of 25 feet, applied to an ot-wheel, will drive a hammer of 1500 lbs. in weight from 100 to 120 blows ute, with a lift of from 1 to 1.5 feet.*

ime of water of 21.5 cube feet per second, with a fall of 12 *having a great height* of water above its summit, being *drive a hammer of* 500 lbs. in weight 100 blows per min *Estimate of* power 31.5 horses.

* *water required for a* hammer increases in a much greater ratio than *nearly as cube of velocity.*

A Stream and Overshot Wheel of following dimensions—viz., height of head to centre of opening, 24.875 ins.; opening, 1.75 by 80 ins.; wheel, 22 feet in diameter by 8 feet face; 52 buckets, each 1 foot in depth, making 3.5 revolutions per minute—drove 3 run of 4.5 feet stones 130 revolutions per minute, with all attendant machinery, and ground and dressed 25 bushels of wheat per hour.

4.5 bushels Southern and 5 bushels Northern wheat are required to make 1 barrel of flour.

A Breast-wheel and Stream of following dimensions—viz., head, 20 feet; height of water upon wheel, 16 feet; opening, 18 feet by 2 ins.; diameter of wheel, 26 feet 4 ins.; face of wheel, 20 feet 9 ins.; depth of buckets, 15.75 ins.; number of buckets, 70; revolutions, 4.5 per minute—drove 6144 self-acting mule spindles; 160 looms, weaving printing-cloths 27 ins. wide of No. 33 yarn (33 hanks to a lb.), and producing 24000 hanks in a day of 11 hours.

Horizontal Wheels.

In horizontal water-wheels, water produces its effect either by *Impact*, *Pressure*, or *Reaction*, but never directly by its weight.

These wheels are therefore classed as Impact, Pressure, and Reaction, but are now designated by the generic term of Turbine.

Turbines.

Turbines, being operated at a higher number of revolutions than Vertical Wheels, are more generally applicable to mechanical purposes; but in operations requiring low velocities, Vertical Wheel is preferred.

For variable resistances, as rolling-mills, etc., Vertical Wheel is far preferable, as its mass serves to regulate motion better than a small wheel.

In economy of construction there is no essential difference between a Vertical Wheel and a Turbine. When, however, fall of water and volume of it are great, the Turbine is least expensive. Variations in supply of water affect vertical wheels less than Turbines.

Durability of a Turbine is less than that of a Vertical Wheel; and it is indispensable to its operation that the water should be free from sand, silt, branches, leaves, etc.

With Overshot and Breast Wheels, when only a small quantity of water is available, or when it is required or becomes necessary to produce only a portion of the power of the *fall*, their efficiency is relatively increased, from the blades being but proportionately filled; but with Turbines the effect is contrary, as when the sluice is lowered or supply decreased water enters the wheel under circumstances involving greater loss of effect. To produce maximum effect of a stream of water upon a wheel, it must flow without impact upon it, and leave it without velocity; and distance between point at which the water flows upon a wheel and level of water in reservoir should be as short as practicable.

Small wheels give less effect than large, in consequence of their making a greater number of revolutions and having a smaller water arc.

In *High-pressure Turbines* reservoir (of wheel) is enclosed at top, and water is admitted through a pipe at its side. In *Low-pressure*, water flows into reservoir, which is open.

Turbines working under water, height is measured from surface of water in supply to surface of discharged water or race; and when they work [illegible], height is measured from surface in supply to centre of wheel.

To obtain maximum effect from water, velocity of it, when leaving, should be the least practicable.

Efficiency is greater when sluice or supply is wide open, and it is less a: fected by head than by variations in supply of water. It varies but litt with velocity, as it was ascertained by experiment that when 35 revolutior gave an effect of .64, 55 gave but .66.

When Turbines operate under water, the flow is always full through them hence they become *Reaction-wheels*, which are the most efficient.

Experiments of Morin gave efficiency of Turbines as high as .75 of powe

Angle of plane of water entering a Turbine, with inner periphery of i should be greater than 90°, and angle which plane of water leaving reservo makes with inner circumference of Turbine should be less than 90°.

When Turbines are constructed without a *guide curve**, angle of plane (flowing water and inner circumference of wheel = 90°.

Great curvature involves greater resistance to efflux of water; and hen(it is advisable to make angle of plane of entering water rather obtuse tha acute, say 100°; angle of plane of water leaving, then, should be 50°, if ir ternal pressure is to balance the external; and if wheel operates free (water, it may be reduced to 25° and 30°.

If blades are given increased length, and formed to such a hollow curv that the water leaves wheel in nearly a horizontal direction, water then bot impinges on blades and exerts a pressure upon them; therefore effect : greater than with an impact-wheel alone.

Turbines are of three descriptions: Outward, Downward, and Inward flov

Outward-flow Turbines.

FOURNEYRON TURBINE, as recently constructed, may be considered as or of the most perfect of horizontal wheels; it operates both in and out (back-water, is applicable to high or low falls, and is either a high or lo pressure turbine.

In high-pressure, the reservoir is closed at top and the water is led to through a pipe. In low-pressure, the water flows directly into an open re: ervoir. Pressure upon the step is confined to weight of wheel alone.

Fourneyron makes angle of plane of water entering = 90°, and angle (plane of water leaving = 30°.

Efficiency is reduced in proportion as sluice is lowered, for action of wat on wheel is less favorably exerted. M. Morin tested a Fourneyron turbir 6.56 feet in diameter, and he found that efficiency varied from a minimu of 24, to 79 per cent., when supply of water was reduced to .25 of full suppl In practice, radial length of blades of wheel is .25 of radius, for falls not e: ceeding 6.5 feet, .3 for falls of from 6.5 to 19 feet, and .66 for higher falls.

To Compute Elements and Results.

High Pressure, $6.6\sqrt{h} = v$; $\frac{V}{v} = A$; $\frac{\sqrt{1.77\,V}}{\sqrt{h}} = D$†; $12.6\,\frac{HP}{h} = V$; a

$.079\,V\,h = HP$. *h representing head of water, v velocity of turbine at periphery p minute, and D internal diameter of turbine, all in feet, V volume of water in cube f per second, A sum of area of orifices in sq. feet, and HP effective horse-power.*

1.2 D = external diameter of turbine in feet, when it is more than 6 feet, and 1 when it is less than 6 feet. Number of guides = number of blades ‡ when less th 24, and number ÷ 3 when greater than 24. Area of section of supply pipe = .4

For construction of blades and guides, see Molesworth, London, 1882, page 5

* *Guide curves are plates upon centre body of a Turbine, which give direction to flow or to blades of wheel which surround them.*

† *In extreme cases of very high falls diameter given by this formula may be increased.*

‡ *Fourneyron's rule for the number of blades is constant number 36, irrespective of size*

Operation of High-Pressure Turbines.

h	30	40	50	60	70	80	90	100	120	140	160	180	[illegible]
V	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.27	1.05	.9	.8	.7	[illegible]
v	36	42	47	51	55	59	63	66	73	78	84	89	[illegible]

h = head of water in feet, V volume of water in cube feet required for each [illegible] *and v velocity of periphery of turbine in feet per second.*

Boyden Turbine.—Mr. —— Boyden, of Massachusetts, designe[d] outward-flow turbine of 75 HP, which realized an efficiency of 88 per [cent.] Peculiar features, as compared with a Fourneyron turbine, are, 1st, and [most] important, the conduction of the water to turbine through a vertical t[run]cated cone, concentric with the shaft. The water, as it descends, acqui[res] gradually increasing velocity, together with a spiral movement in dire[ction] of motion of wheel. The spiral movement is, in fact, a continuation o[f] motion of the water as it enters cone.—2d. Guide-plates at base are incl[ined] so as to meet tangentially the approaching water.—3d. A "diffuser," or a[nnu]lar chamber surrounding wheel, into which water from wheel is discha[rged.] This chamber expands outwardly, and, thus escaping velocity of wat[er is] eased off and reduced to a fourth when outside of diffuser is reached. [Effect] of diffuser is to accelerate velocity of water through machine; and ga[in in] efficiency is 3 per cent. Diffuser must be entirely submerged. *(D. K. C*

Poncelet Turbine.—This wheel is alike to one of his undershot-w[heels,] set horizontally, and it is the most simple of all horizontal wheels.

To Compute Elements of General Proportion a[nd] Results. *(Lt. F. A. Mahan, U. S. A.)*

$.0425\, D^2 h \sqrt{h} = HP$; $4.85 \sqrt{\dfrac{P}{h\sqrt{h}}} = D$; $.5\, D^2 \sqrt{h} = V$; $.1\, D = H$; $4.49\sqrt{}$ [illegible]

$3\,(D + 10) = N$; $\dfrac{D}{N} = w$; $\dfrac{4\,D}{N} = W$; $D - \dfrac{S\,D}{N} = d$; $.5\, N$ to $.75\, N = n$; $\dfrac{d}{n}$ [illegible]

and C coefficient for V′ in terms of $V = \dfrac{V'}{V}$. *D and d representing exterior a[nd in]terior diameters of wheel, H and h heights of orifices of discharge at outer c[ircum]ference and of fall acting on wheel, w and w′ shortest distances between two ad[jacent] blades and two adjacent guides, all in feet, V, V′, and v velocities due to fall o[f water] passing through narrowest section of wheel, and of interior circumference of* [illegible] *all in feet per second, N and n numbers of blades and guides, and HP actual* [illegible] *power.*

For falls of from 5 feet to 40, and diameters not less than 2 feet, $n\,w$ sho[uld be] equal to diameter of wheel. H equal to $.1$ D, $n\,w' = d$, and $4\,w$ = width of c[rown.] For falls exceeding this, H should be smaller, in proportion to diameter of wh[eel.]

Downward-flow Turbines.

In turbines with downward flow, wheel is placed below an annular [set] of guide-blades, by which water is conducted to wheel. The water st[rikes] curved blades, and falls vertically, or nearly so, into tail-race; conseque[ntly] centrifugal action is avoided, and downward flow is more compact.

Fontaine Turbine yields an efficiency of 70 per cent., when [fully] charged. When supply of water is shut off to .75, by sluice, efficien[cy is] 57 per cent. Best velocity at mean circumference of wheel is equal t[o] [illegible] of that due to height of fall. It may vary .25 of this either [way without] materially affecting efficiency.

[illegible] ation the water in race is in immediate contact with wheel, a[nd] [illegible] greatest when sluice is fully opened. Its efficiency, also, [illegible] [v]ariations of head of flow than in volume of water su[pplied] [illegible] adapted for Tide-mills.

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ing a Turbine,

Jonval Turbine.—This wheel is essentially alike in its principal propor tions to Fontaine's, and in principle of operation it is the same. Water i race must be at a certain depth below wheel.

For convenience, it is placed at some height above level of tail-race, withi an air-tight cylinder, or "draft-tube," so that a partial vacuum or reductio of pressure is induced under wheel, and effect of wheel is by so much in creased. Resulting efficiency is same as if wheel was placed at level of tail race; and thus, while it may be placed at any level, advantage is taken o whole height of fall, and its efficiency decreases as volume of water is di minished or as sluice is contracted.

To Compute Elements and Results.

Low Pressure.—For falls of 30 feet and less.

$$6\sqrt{h}=v;\quad =\frac{V}{v}=A;\quad \frac{\sqrt{1.77\,V}}{\sqrt{h}}=D^*;\quad 12.7\frac{HP}{h}=V;\quad \text{and } .079\,V\,h=HP.$$

h representing head of water, v velocity of turbine at periphery per minute, and I *internal diameter of turbine, all in feet,* V *volume of water in cube feet per second* A *sum of area of orifices in sq. feet, and* HP *effective horse-power.*

1.2 D = external diameter of turbine in feet, when it is more than 6 feet, and 1.. when it is less than 6 feet. Number of guides = number of blades† when less tha 24, and number ÷ 3 when greater than 24. Area of section of supply-pipe = .4 V.

For construction of blades and guides, see Molesworth, London, 1882, page 540.

Low-Pressure Turbines. (*Molesworth.*)

Head.	v	5 HP V	5 HP R	10 HP V	10 HP R	15 HP V	15 HP R	20 HP V	20 HP R	30 HP V	30 HP R	40 HP V	40 HP R	50 HP V	50 HP R
2.5	9.48	25	34	50	24	75	20	100	17	—	—	—		—	—
5	13.38	12.5	81	25	57	38	47	50	41	75	33	100	28	126	2
7.5	16.38	8.5	136	17	97	25	79	33	68	51	56	68	48	85	4
0	18.96	6.3	180	12.6	128	19	105	25	90	38	75	50	64	63	5
5	23.22	4.2	319	8.4	226	12.6	185	17	160	25	131	33	113	42	10
0	26.82	—	—	6.3	329	9.3	273	12.6	232	18.9	194	25	164	31	14
5	30	—	—	—	—	7.5	358	10	310	15	253	20	220	25	19
0	32.88	—	—	—	—	—	—	8.4	380	12.6	310	17	268	21	24

v representing velocity of centre of blades in feet and V *volume of water, in cub feet, both per second,* R *revolutions per minute, and* HP *effective horse-power.*

$$\textit{Vertical Shaft.}\quad \sqrt[3]{\frac{230\,HP}{R}}=\textit{diameter of shaft in ins.}$$

Inward-flow Turbine.

Inward-flow Turbine.—Inward-flow or vortex wheel is made wit radiating blades, and is surrounded by an annular case, closed externally and open internally to wheel, having its inner circumference fitted with fou curved guide-passages. The water is admitted by one or more pipes to th case, and it issues centripetally through the guide-passages upon circum ference of wheel. The water acting against the curved blades, wheel i driven at a velocity dependent on height of fall, and water having expende its force, passes out at centre. This wheel has realized an efficiency as hig as 77.5 per cent. It was originally designed by Prof. James Thomson.

Swain Turbine.—Combines an inward and a downward discharge. Re ceiving edges of buckets of wheel are vertical opposite guide-blades, an lower portions of the edges are bent into form of a quadrant. Each buc thus forms, with the surface of adjoining bucket, an outlet which comb an inward and a downward discharge. One, 72 ins. in diameter, was

* *In extreme cases of very high falls* diameter given by this formula may be increased.
† *Fourneyron's rule for the number of blades* is constant number 36, irrespective of size of

by Mr. J. B. Francis, for several heights of gate or sluice, from 2 to 13.6 ins., and circumferential velocities of wheel ranging from 60 to 80 per cent. of respective velocities due to heads acting on wheel.

For a velocity of 60 per cent., and for heights of gate varying within limits already stated, efficiency ranged from 47.5 to 76.5 per cent., and for a velocity of 80 per cent. it ranged from 37.5 to 83 per cent. Maximum efficiency attained was 84 per cent., with a 12-inch gate and a velocity-ratio of 76 per cent.; but from 9-inch to 13-inch gate, or from .66 gate to full gate, maximum efficiency varied within very narrow limits—from 83 to 84 per cent.,—velocity-ratios being 72 per cent. for 9-inch gate, and 76.5 per cent. for full gate. At half-gate, maximum efficiency was 78 per cent., when velocity-ratio was 68 per cent. At quarter-gate, maximum efficiency was 61 per cent., and velocity-ratio 66 per cent.

TREMONT TURBINE, as observed by Mr. Francis, in his experiments at Lowell, Mass., gave a ratio of effect to power as .793 to 1.

VICTOR TURBINE is alleged to have given an effect of .88 per cent. under a head of 18.34 feet, with a discharge of 977 cube feet of water per minute, and with 343.5 revolutions.

Tangential Wheel.

Wheels to which water is applied at a portion only of the circumference are termed tangential. They are suited for very high falls, where diameter and high tangential velocity may be combined with moderate revolutions. The *Girard* turbine belongs to this class. It is employed at Goeschenen station for St. Gothard tunnel; it operates under a head of 279 feet. The wheels are 7 feet 10.5 ins. in diam., having 80 blades, and their speed is 160 revolutions per minute, with a maximum charge of water of 67 gallons per second. An efficiency of 87 per cent. is claimed for them at the Paris water-works; ordinarily it is from 75 to 80 per cent. (*D. K. Clark.*)

Impact and Reaction Wheel.

IMPACT-WHEEL.—Impact Turbine is most simple but least efficient form of impact-wheel. It consists of a series of rectangular buckets or blades, set upon a wheel at an angle of 50° to 70° to horizon; the water flows to blades through a pyramidal trough set at an angle of 20° to 40°, so that the water impinges nearly at right angles to blades. Effect is .5 entire mechanical effect, which is increased by enclosing blades in a border or frame.

If buckets are given increased length, and formed to such a hollow curve that the water leaves wheel in nearly a horizontal direction, the water then impinges on buckets and exerts a pressure upon them; effect therefore is greater than with the force of impact alone.

By deductions of Weisbach it appears that effect of impact is only half available effect under most favorable circumstances.

REACTION-WHEEL.—Reaction of water issuing from an orifice of less capacity than section of vessel of supply, is *equal to weight of a column of water, basis of which is area of orifice or of stream, and height of which is twice height due to velocity of water discharged.*

Hence, the expression is $2 . \frac{v^2}{2g} a w = R$. *w representing weight of a cube foot of water in lbs., and a area of opening in sq. feet.*

WHITELAW'S is a modification of Barker's; the arms taper from centre towards circumference and are curved in such a manner as to enable the water to pass from central openings to orifices in a line nearly right and radial, when instrument is operating at a proper velocity; in order that very little centrifugal force may be imparted to the water by the revolution of the ar... consequently a minimum of frictional resistance is ...

...r.

Turbine 9.55 feet in diameter, with orifices 4.944 ins. in diameter, oper- by a fall of 25 feet, gave an efficiency of 75 per cent., including friction aring of an inclined plane.

en a reaction wheel is loaded, so that height due to velocity, corresponding to .ty of rotation v, is equal to fall, or $\frac{v^2}{2g} = h$, or $v = \sqrt{2gh}$, there is a loss of 17 ɜnt. of available effect; and when $\frac{v^2}{2g} = 2h$, there is a loss of but 10 per cent.; ·hen $\frac{v^2}{2g} = 4h$, there is a loss of but 6 per cent. Consequently, for moderate and when a velocity of rotation exceeding velocity due to height of fall may ɔpted, this wheel works very effectively.

ciency of wheel is but one half that of an undershot-wheel.

ıen sluice is lowered, so that only a portion of wheel is opened, efficiency Reaction-wheel is less than that of a Pressure Turbine.

Ratio of Effect to Power of several Turbines is as follows:

ılet	.65 to .75 to 1	Jonval	.6 to .7 to 1
ıeyron	6 to .75 to 1	Fontaine	6 to 7 to 1

.RKER'S MILL.—Effect of this mill is considerably greater than that h same quantity of water would produce if applied to an undershot- l, but less than that which it would produce if properly applied to an ıhot-wheel.

· a description of it, see *Grier's Mechanics' Calculator*, page 234; and for its ılas, see *London Artisan*, 1845, page 229.

IMPULSE AND RESISTANCE OF FLUIDS.

ɒpulse and Resistance of Water.—Water or any other fluid, ı flowing against a body, imparts a force to it by which its condition of on is altered. Resistance which a fluid opposes to motion of a body not essentially differ from Impulse.

ıpulse of one and same mass of fluid under otherwise similar circum- ɔes is proportional to relative velocities $c \mp v$ of fluid.

ır an equal transverse section of a stream, the impulse against a surface st increases as square of velocity of water.

ıpulse against Plane Surfaces.—The impulse of a stream of water de- ls principally upon angle under which, after impulse, it leaves the water; nothing if the angle is 0, and a maximum if it is deflected back in a parallel to that of its flow, or 180°, $2\frac{c \mp v}{g} V w = P$*.

ʼhen Surface of Resistance is a Plane, and $= 90°$, then $\frac{c \mp v}{g} V w = P$, and *a surface at rest*, $2 a h w = P$. *a representing area of opening in sq. feet.* $= 2 A h w$; *c and v representing velocities of water and of surface upon which it nges in feet per second, w weight of fluid per cube foot in lbs., A transverse section ream in sq. ins., and c ∓ v relative motions of water and surf*

ormal impulse of water against a plane surface is e[illegible] ·ht column which has for its base transverse section ude twice *height due to its velocity*, $2h = 2\frac{c^2}{2g}$.

sistance of a fluid to a body in motion is same as [illegible] *g with same velocity* against a body at rest.

* Weisbach, New York, 1870, vol. i. page 1008.

To Compute Velocities of Elastic Bodies after Im[pact]

When Impelled in One Direction. $\frac{\overline{B-b}\,V+2\,b\,v}{B+b}=R$, and $\frac{2\,B\,V-\overline{B-[b]}}{B+b}$

Illustration.—Assume elements as preceding.

$\frac{\overline{50-30}\times 7+2\times 30\times 3}{50+30}=\frac{320}{80}=4$ *feet*, and $\frac{2\times 50\times 7-\overline{50-30}\times 3}{50+30}=\frac{640}{80}=$

Or, $V-\frac{2\,b}{B+b}\overline{V-v}=$ velocity of R, and $v+\frac{2\,B}{B+b}\overline{V-v}=$ velocity o[f]

When Impelled in Opposite Directions.

$$\frac{\overline{B-b}\,V\sim 2\,b\,v}{B+b}=R, \text{ and } \frac{2\,B\,V+\overline{B-b}\,v}{B+b}=r.$$

Illustration.—Assume elements as preceding.

$\frac{\overline{50-30}\times 7\sim 2\times 30\times 3}{50+30}=\frac{140\sim 180}{80}=-.5$ *feet*, and $\frac{2\times 50\times 7+\overline{50-30}}{50+30}$

$\frac{700+60}{80}=9.5$ *feet*. Or, $\frac{2\,b\,(V+v)}{B+b}=$ *velocity lost by* B. As $\frac{2\times 30\times \overline{7+3}}{50+30}$ $=7.5$ *feet*.

When One Body is at Rest. $\frac{V\,\overline{B-b}}{B+b}=R$, and $\frac{2\,B\,V}{B+b}=r$.

Illustration.—Assume elements as preceding.

$$\frac{7\times \overline{50-30}}{50+30}=\frac{140}{80}=1.75 \textit{ feet}, \text{ and } \frac{2\times 50\times 7}{50+30}=\frac{700}{80}=8.75 \textit{ feet}.$$

To Compute Velocities of Imperfect Elastic Bodies a[fter] Impact.

Effect of Collision is increased over that of perfectly inelastic bodie[s] not doubled, as in case of perfectly elastic bodies; it must be multipli[ed] $1+\frac{n}{m}$ or $\frac{m+n}{m}$, when $\frac{n}{m}$ represents degree of elasticity relative to both [per]fect inelasticity and elasticity.

Moving in same Direction. $V-\frac{m+n}{m}\times\frac{b}{B+b}(V-v)=R$; and $v+\frac{[m+n]}{[m]}\times\frac{B}{B+b}(V-v)=r$. *m and n representing ratio of perfect to imperfect elastic[ity].*

Illustration.—Assume elements as preceding. m and $n=2$ and 1.

$7-\frac{2+1}{2}\times\frac{30}{50+30}\times\overline{7-3}=7-1.5\times\frac{30}{80}\times 4=7-2.25=4.75$ *feet*, and $\frac{2+1}{2}\times\frac{50}{50+30}\times\overline{7-3}=3+3.75=6.75$ *feet*.

When Moving in Opposite Directions.

$$V-\frac{m+n}{m}\times\frac{b\,(V+v)}{B+b}=R, \text{ and } \frac{m+n}{m}\times\frac{B}{B+b}\times(V+v)-v=r.$$

[Wh]en One Body is at Rest. $\frac{V\left(B-\frac{n}{m}b\right)}{B+b}=R$, and $\frac{B\,V\left(1+\frac{n}{m}\right)}{B+b}=r$.

[Illust]ration.—Assume elements of preceding case.

$\frac{1}{2}\times 30)$ ... $\overline{30-15} = 3.0625$ feet, and $\frac{50\times 7\times(1+\frac{1}{2})}{50+[30]}$

LIGHT.

:T is similar to Heat in many of its qualities, being emitted in f rays, and subject to same laws of reflection.

of two kinds, *Natural* and *Artificial;* one proceeding from Sun ırs, the other from heated bodies.

s shine in dark only at a temperature from 600° to 700°, and in ıt at 1000°.

ısity of Light is inversely as square of distance from luminous

city of Light of Sun is 185 000 miles per second.

lard of Intensity or of comparison of light between different methods ıination is a Sperm Candle "short 6," burning 120 grains per hour.

Candles.

ermaceti candle .85 of a inch in diameter consumes an inch in length ır.

Decomposition of Light.

	Maximum Ray.	Contrasts. Primary.	Second'y.	Tertiary.	Combinations. Primary.	Secondary.	Tertiary.
...	Chemical.	—	—	—	Blue...	Green..	—
..	—	—	—	Brown.	Yellow.		Dark
...	Electrical.	Blue.	—	—	Blue...	Purple.	Green.
...	—	—	Green.	Green.	Red....	Orange.	Gray.
..	Light.	Yellow.	—	—	—	Green..	
...	—	—	Orange.	Broken.	Yellow.	Purple.	Brown.
...	Heat.	Red.	Purple.	Green.	Red....	Orange.	

lors of spectrum, when combined, are white.

sumption and Comparative Intensity of Light of Candles.

Candle.	No. in a Lb.	Diameter.	Length.	Consumption per Hour.	Light comp'd with Carcel.
		Inch.	Ins.	Grains.	
....	3	1	12	135	.09
....	3	.875	15		
ceti	3	.9	15	156	.09
....	4	.8	13.5		
....	6	.84	8.5		
....	3	1	12.5	[illegible]	
....	3	.9	15		
....	4	.8	13.75		

Compared with 1000 Cube Feet of Gas.

:.	Gas=1.	Consumption.	Light.	Consumption for equal Light.	Candle.	Gas=1.	Consumption.
		Lbs.	*Lbs.*				Lbs.
'.	*.098*	*3.5*	*35.5*	103	Adamantine.	.108	5.1
	.095	*3.9*	*41.1*	120	Tallow......	.074	5.1

ıustion of oil in an ordinary lamp, a straight or horizonta economy over one irregularly cut.

Relative Intensity, Consumption, Illumination, and Cost of various Modes of Illumination.

Oil at 11 cents, Tallow at 14 cents, Wax at 52 cents, and Stearine at 32 cents per lb. 100 cube feet coal gas at 14 cents, and 100 cube feet of oil gas at 52 cents.

Illuminator.	Illumination. Carcel Lamp = 100.	Actual Cost per Hour.	Cost for equal Intensity.	Illuminator.	Illumination. Carcel Lamp = 100.	Actual Cost per Hour.	Cost for equal Intensity.
		Cents.	Per H'r.			Cents.	Per H'r.
Carcel Lamp	100	.87	.87	Stearine Candle 5 to lb.	66.6	.59	[illegible]
Lamp with inverted reserv'r.	57.8	.89	.99	Tallow " 6 "	54	.25	[illegible]
Astral Lamp	48.7	.56	1.78	Sperm " 6 "	67.5	.89	[illegible]
Wax Candle 6 to lb.	61.6	.92	6.31	Coal Gas	—	1.22	[illegible]
				Oil Gas	—	1.25	[illegible]

1000 cube feet of 13-candle coal gas is equal to 7.5 gallons sperm oil, 52.9 lbs. [illegible] and 44.6 lbs. sperm candles.

Candles, Lamps, Fluids, and Gas.

Comparison of several Varieties of Candles, Lamps, and Fluids, with Coal Gas, deduced from Reports of Com. of Franklin Institute, and of A. Frye, M.D., etc.*

Candle.	Intensity of Light.†	Light at Equal Costs.	Cost compared with Gas for Equal Light.	Candle.	Intensity of Light.†	Light at Equal Costs.	Cost compared with Gas for Equal Light.
Diaphane	.7	.5	15.1	Tallow, short 6's, double wick	1	1	[illegible]
Spermaceti, short 6's	.8	.54	16.2	Wax, short 6's	.8	.61	[illegible]
Tallow, short 6's, single wick	.58	.85	7.5	Palm oil	7	.77	[illegible]

* City of Philadelphia. † Compared with a fish-tail jet of Edinburgh gas, containing 12 parts of condensable matter and consuming 1 cube foot per hour.

Lamp and Fluid.	Intensity of Light.	Light at Equal Cost.	Time of Burning 1 Pint of Oil.	Lamp and Fluid.	Intensity of Light.	Light at Equal Cost.	Time of Burning 1 Pint of Oil.
Carcel.			Hours.				Hours.
Sperm oil, *max'm*	2.15	1.8	6.32	Gas	1	1	[illegible]
" *mean.*	1.22	1.35	9.87	Semi-solar, Sperm oil	1.15	.93	6
" *min'm*	.69	1.2	14.6	Solar, Sperm oil	1.76	1.55	8
Lard oil	.77	.97	11.3	Camphene	1.75	3.08	9

Loss of Light by Use of Glass Globes.

Clear Glass, 12 per cent. | Half ground, 35 per cent. | Full ground, 40 per c[ent.]

Refraction.

Relative Index of Refraction—Is, Ratio of sine of angle of incidence to sine of angle of refraction, when a ray of light passes from one medium into another.

Absolute Index or Index of Refraction—Is, When a ray passes from a vacuum into any medium, the ratio is greater than unity.

Relative index of refraction from any medium, as A, into another, as B, is also equal to absolute index of B, divided by absolute index of A.

Absolute index of air is so small, that it may be neglected when compared with liquids or solids; strictly, however, relative index for a ray passing from air into a given substance must be multiplied by absolute index for air, in order to obtain like index of refraction for the substance.

Mean Indices of Refraction.

[illegible]	1	Glass, fluid	1.58 to 1.64	Humors of eye	
	1.37			Salt, rock	
	1.54	" crown	1.53 to 1.56	Water, fresh	
	1.34			" sea	

Gas.

rt.—A retort produces about 600 cube feet of gas in 5 hours with a of about 1.5 cwt. of coal, or 2800 cube feet in 24 hours.

stimating number of retorts required, one fourth should be added for ınder repairs, etc.

sure with which gas is forced through pipes should seldom exceed 2.5 water at the Works, or leakage will exceed advantages to be obtained ıcreased pressure.

average mean pressure in street mains is equal to that of 1 inch of

n pipes are laid at an inclination either above or below horizon, a cor- . will have to be made in estimating supply, by adding or deducting h from initial pressure for every foot of rise or fall in the length of pipe.

customary to locate a governor at each change of level of 30 feet.

ninating power of coal-gas varies from 1.6 to 4.4 times that of a tallow 6 to a lb.; consumption being from 1.5 to 2.3 cube feet per hour, and gravity from .42 to .58.

her the flame from a burner greater the intensity of the light, the ffective height being 5 ins.

dard of gas burning is a 15-hole Argand lamp, internal diameter .44 himney 7 ins. in height, and consumption 5 cube feet per hour, giving from ordinary coal-gas of from 10 to 12 candles, with Cannel coal o to 24 candles, and with rich coals of Virginia and Pennsylvania of 4 to 16 candles.

'hiladelphia, with a fish-tail burner, consuming 4.26 cube feet per hour, ıating power was equal to 17.9 candles, and with an Argand burner, ıing 5.28 cube feet per hour, illuminating power was 20.4 candles.

which at level of sea would have a *Value* of 100, would have but 60 of Mexico.

rnal lights require 4 cube feet, and external lights about 5 per hour. large or Argand burners are used, from 6 to 10 are required.

ordinary single-jet house burner consumes 5 to 6 cube feet per hour.

et-lamps in city of New York consume 3 cube feet per hour. In some 4 and 5 cube feet are consumed. Fish-tail burners for ordinary coal ısume from 4 to 5 cube feet of gas per hour.

ıbe foot of good gas, from a jet .033 inch in diameter and height of of 4 ins., will burn for 65 minutes.

n Gas.—Jet .033, flame 5 ins., 1.25 cube feet per hour.

fiers.—Wet purifiers require 1 bushel of lime mixed with 48 bushels er for 10000 cube feet of gas.

purifiers require 1 bushel of lime to 10000 cube feet of gas, and 1 cial foot for every 400 cube feet of gas.

ısity of Light with Equal Volumes of Gas from different Burners.

Equal to Spermaceti Candle burning 120 Grains per Hour.

urners.	Expenditure in Cube Feet per Hour. 1	2	3	4	Burners.	Expenditure … Fe… 1
, 1 foot....	2.6	—	—	—	Argand, 16 holes....	.3?
No. 3	3.5	4	4.2	—	Argand, 24 holes....	.3
....	3	4.1	4.3	4.5	Argand, 28 holes....	.3

Volume of Gas obtained from a Ton of Coal, Resi

Material.	Cube Feet.	Material.	Cube Feet.	Material.
Boghead Cannel...	13 334	Cumberland........	9 800	Pittsburgh.....
Wigan Cannel.....	15 426	English, mean......	11 000	Resin..........
Cannel..........	8 960 15 000	Newcastle........	9 500 10 000	Scotch.........
Cape Breton, "Cow Bay," etc..........	9 500	Oil and Grease.....	23 000	Virginia.........
		Pictou and Sidney..	8 000	" West'n.
		Pine wood.........	11 800	Walls-end......

1 Chaldron Newcastle coal, 3136 lbs., will furnish 8600 cube feet c a specific gravity of .4, 1454 lbs. coke, 14.1 gallons tar, and 15 gall(moniacal liquor.

Australian coal is superior to Welsh in producing of gas.

Wigan Cannel, 1 ton, has produced coke, 1326 lbs.; gas, 338 lb 250 lbs.; loss, 326 lbs.

Peat, 1 lb. will produce gas for a light of one hour.

Fuel, required for a retort 18 lbs. per 100 lbs. of coal.

In distilling 56 lbs. of coal, volume of gas produced in cube feet distillation was effected in 3 hours was 41.3, in 7, 37.5, in 20, 33.5, 25, 31.7.

Flow of Gas in Pipes.

Flow of Gas is determined by same rules as govern that of flow of Pressure applied is indicated and estimated in inches of water, usually .5 to 1 inch.

Volumes of gases of like specific gravities discharged in equal time horizontal pipe, under same pressure and for different lengths, are in as square roots of lengths.

Velocity of gases of different specific gravities, under like pressure, versely as square roots of their gravities.

By experiment, 30 000 cube feet of gas, specific gravity of .42, we charged in an hour through a main 6 ins. in diameter and 22.5 feet in l

Loss of volume of discharge by friction, in a pipe 6 ins. in diameter mile in length, is estimated at 95 per cent.

Diameter and Length of Gas-pipes to transmit g Volumes of Gas to Branch-pipes. (*Dr. Ure.*)

Volume per Hour.	Diameter.	Length.	Volume per Hour.	Diameter.	Length.	Volume per Hour.	Diameter.	L
Cube Feet.	Ins.	Feet.	Cube Feet.	Ins.	Feet.	Cube Feet.	Ins.	
50	.4	100	1000	3.16	1000	2000	7	
250	1	200	1500	3.87	1000	6000	7.75	
500	1.97	600	2000	5.32	2000	6000	9.21	
700	2.65	1000	2000	6.33	4000	8000	8.95	

Regulation of Diameter and Extreme Length of T ing, and Number of Burners permitted.

Diameter of	Length.	Capacity of Meters.	Burners.	Diameter of Tubing.	Length.	Capacity of Meters.	Bu
		Light.	No.	Ins.	Feet.	Light.	
		3	9	.75	50	30	
		5	15	1	70	45	
		10	30	1.25	100	60	
			60	1.5	150	100	

ıperature of Gases.—Combustion of a cube foot of common gas will ·50 lbs. of water 1°.

Services for Lamps.

Length from Main.	Diameter of Pipe.	Lamps.	Length from Main.	Diameter of Pipe.	Lamps.	Length from Main.	Diameter of Pipe.
Feet.	Ins.	No.	Feet.	Ins.	No.	Feet.	Ins.
40	·375	10	100	·75	25	180	1·5
40	·5	15	130	1	30	200	1·75
50	.625	20	150	1.25			

ımes of Gas Discharged per Hour under a Pressure of Half an Inch of Water.

Specific Gravity .42.

of ıg.	Volume.	Diam. of Opening.	Volume.	Diam. of Opening.	Volume.	Diam. of Opening.	Volume.
	Cube Feet.	Ins.	Cube Feet.	Ins.	Cube Feet.	Ins.	Cube Feet.
	80	·75	723	1.125	1625	1·5	2 885
	321	1	1287	1.25	2010	5	46 150

›ompute Volume of Gas Discharged through a Pipe.

$\sqrt{\frac{d^5 h}{G\,l}} = V$, and $.063 \sqrt[5]{\frac{V^2 G\,l}{h}} = d$. *d representing diameter of pipe, and ht of water in ins., denoting pressure upon gas, l length of pipe in yards,* G *: gravity of gas, and* V *volume in cube feet per hour.*

ay be assumed for ordinary computation at .42, and *h* .5 to 1 inch.

STRATION.—Assume diameter of pipe 1 inch, pressure 1.68 ins., and length › 1 yard.

$$1000 \times \sqrt{\frac{1 \times 1.68}{.42 \times 1}} = 1000 \times \sqrt{\frac{1.68}{.42}} = 2000 \textit{ cube feet},$$

$$\text{and } .063 \times \sqrt[5]{\frac{4\,000\,000 \times .42 \times 1}{1.68}} = \sqrt[5]{\frac{1\,680\,000}{1.68}} = 1.05 \textit{ ins.}$$

E.—For tables deduced by above formulas see Molesworth, 1878, page 226.

nensions of Mains, with Weight of One Length.

ter in ins.....	4	6	8	9	10	14	18	20
ı in feet......	9	9	9	9	9	9	9	9
ıess in ins. ...	·375	·375	·5	·5	·5	.625	·75	·75
t in lbs.......	288	224	400	454	489	868	1316	1484

GAS ENGINES.

he Lenoir engine, the best proportions of air and gas are, for common volumes of air to 1 of gas, and for cannel gas, 11 of air to 1 of gas.

: time of explosion is about the 27th part of a second.

engine, having a cylinder 4.625 ins. in diameter and 8.75 ins. stroke of , making 185 revolutions per minute, develops a half horse-power.

Distribution of Heat Generated in the Cylinder. (*M. Tresca.*)

	Per cent.		Per cent.
ated by the water and prod- of combustion.	69	Losses............................	27
rted into work...............	4		100

ce efficiency as determined by the brake = 4 per cent.

Atmospheric Gas Engine.

le-acting cylinder 6 ins. in diameter, making 81 strokes per m' *· IP, and the gas* consumed per minute for cylinder 20 cube fe· *cube feet. (M. Tresca.)*

LIMES, CEMENTS, MORTARS, AND CONCRETES.

*Essentially from a Treatise by Brig.-Gen'l Q. A. Gillmore, U.S.A.**

Lime.

Calcination of marble or any pure limestone produces *lime (quick-lime)*. Pure limestones burn white, and give richest limes.

Finest calcareous minerals are rhombohedral prisms of calcareous spar, the transparent double-reflecting Iceland spar, and white or statuary marble.

Property of hardening under water, or when excluded from air, conferred upon a paste of lime, is effected by presence of foreign substances—as silicum, alumina, iron, etc.—when their aggregate presence amounts to .1 of whole.

Limes are classed: 1. Common or Fat limes, which do not set in water. 2. Poor or Meagre, mixed with sand, which does not alter its condition. 3. Hydraulic Lime, containing 8 to 12 per cent. of silica, alumina, iron, etc., set slowly in water. 4. Hydraulic, containing 12 to 20 per cent. of similar ingredients, sets in water in 6 or 8 days. 5. Eminently Hydraulic, containing 20 to 30 per cent. of similar ingredients, sets in water in 2 to 4 days. 6. Hydraulic Cement, containing 30 to 50 per cent. of argil, sets in a few minutes, and attains the hardness of stone in a few months. 7. Natural Pozzuolanas, including pozzuolana properly so called, Trass or Terras, [illegible] Ochreous earths, Basaltic sands, and a variety of similar substances.

Indications of Limestones. They dissolve wholly or partly in weak acids with brisk effervescence, and are nearly insoluble in water.

Rich Limes are fully dissolved in water frequently renewed, and [illegible] remain a long time without hardening; they also increase greatly in volume, from 2 to 3.5 times their original bulks, and will not harden without the action of air. They are rendered *Hydraulic* by admixture of pozzuolana or trass.

Rich, fat, or *common Limes* usually contain less than 10 per cent. of impurities.

Hydraulic Limestones are those which contain iron and clay, so as to enable them to produce cements which become solid when under water.

Poor Limes have all the defects of rich limes, and increase but slightly in bulk, the poorer limes are invariably basis of the most rapidly-setting and most durable cements and mortars, and they are also the only [illegible] which have the property, when in combination with silica, etc., of [illegible] under water, and are therefore applicable for admixture of hydraulic [illegible] or mortars. Alike to rich limes, they will not harden if in a state of [illegible] under water or in wet soil, or if excluded from contact with the [illegible] or carbonic acid gas. They should be employed for mortar only [illegible] impracticable to procure common or hydraulic lime or cement, in which [illegible] it is recommended to reduce them to powder by grinding.

Hydraulic Limes are those which readily harden under water. The [illegible] valuable or eminently hydraulic set from the 2d to the 4th day after immersion; at end of a month they become hard and insoluble, and at end of [illegible] months they are capable of being worked like the hard, natural [illegible]. They absorb less water than pure limes, and only increase in bulk from [illegible] to 2.5 times their original volume.

* See also his Treatise on Limes, Hydraulic Cements, and Mortars, in Papers on Practical Engineering, Engineer Department, U. S. A.

ıferior grades, or *moderately hydraulic*, require a period of from 15 ɔ days' immersion, and continue to harden for a period of 6 months.

esistance of hydraulic limes increase if sand is mixed in proportion ɔ to 180 per cent. of the part in volume; from thence it decreases.

Vicat declares that lime is rendered hydraulic by admixture with it of from 40 per cent. of clay and silica, and that a lime is obtained which does not ·, and which quickly sets under water.

rtificial Hydraulic Limes do not attain, even under favorable circum-ːes, the same degree of hardness and power of resistance to compression ıtural limes of same class.

ose-grained and densest limestones furnish best limes.

ydraulic limes lose or depreciate in value by exposure to the air.

ıstes of fat limes shrink, in hardening, to such a degree that they can-ɔe used as mortar without a large proportion of sand.

·ènes is a species of ochreous sand. It is found in France. On account e large proportion of clay it contains, sometimes as great as .7, it can be e into a paste with water without any addition of lime; hence it is some-s used in that state for walls constructed *en pisé*, as well as for mortar. ed with rich lime it gives excellent mortar, which attains great hardness ːr water, and possesses great hydraulic energy.

ɔzzuolana is of volcanic origin. It comprises Trass or Terras, the Arènes, ɘ of the ochreous earths, and the sand of certain graywackes, granites, ɜts, and basalts; their principal elements are silica and alumina, the ıer preponderating. None contain more than 10 per cent. of lime.

hen finely pulverized, without previous calcination, and combined with paste t lime in proportions suitable to supply its deficiency in that element, it pos-ːs hydraulic energy to a valuable degree. It is used in combination with rich and may be made by slightly calcining clay and driving off the water of com-·ion at a temperature of 1200°.

ɾick or *Tile Dust* combined with rich lime possesses hydraulic energy.

ɾass or *Terras* is a blue-black trap, and is also of volcanic origin. It ires to be pulverized and combined with rich lime to render it fit for ınd to develop any of its hydraulic properties.

ıeral Gillmore designates the varieties of hydraulic limes as follows: If, after slaked, they harden under water in periods varying from 15 to 20 days after ɾsion, *slightly hydraulic;* if from 6 to 8 days, *hydraulic;* and if from 1 to 4 *eminently hydraulic.*

lverized silica burned with rich lime produces hydraulic lime of ex-ıt quality. Hydraulic limes are injured by air-slaking in a ratio vary-irectly with their hydraulicity, and they deteriorate by age.

ɾ foundations in a damp soil or exposure, hydraulic limes must be ex-ɾely employed.

draulic Lime of Teil is a silicious hydraulic lime; it is slow in setting, ɾing a period of from 18 to 24 hours.

Cements.

draulic Cements contain a larger proportion of silica, alumina ·*han any of preceding* varieties of lime; they do not slake ı *and are superior to the* very best of hydraulic limes, as ı *der water at a moderate* temperature (65°) in from 3 ı *require as many hours.* They do not shrink in hardeni *llent mortar without* any admixture of sand.

When exposed to air, they absorb moisture and carbonic acid gas, and are rapidly deteriorated thereby.

Roman Cement is made from a lime of a peculiar character, found in England and France, derived from argillo-calcareous kidney-shaped stones termed *Septaria.*

It is about .33 strength of Portland, and is not adapted for use with sand.

Rosendale Cement is from Rosendale, New York.

Portland Cement is made in England and France. It requires less water (cement 1, water .29) than Roman cement, sets slowly, and *can be remixed with additional water after an interval of 12 or even 24 hours from its first mixture.*

Property of setting slow may be an obstacle to use of some designations of this cement, as the Boulogne, when required for localities having to contend against immediate causes of destruction, as in sea constructions, having to be executed under water and between tides. On the other hand, a quick-setting cement is always difficult of use; it requires special workmen and an active supervision. A slow setting cement, however, like natural Portland, possesses the advantage of being managed by ordinary workmen, and *it can also be remixed with additional water after an interval of 12 or even 24 hours from its first mixing.*

Conclusions derived from Mr. Grant's Experiments.

1. Portland cement improves by age, if kept from moisture.
2. Longer it is in setting, stronger it will be.
3. At end of a year, 1 of cement to 1 sand is about .75 strength of neat cement, 1 to 2, .5 strength; 1 to 3, .33; 1 to 4, .25; 1 to 5, .16.
4. Cleaner and sharper the sand, greater the strength.
5. Strong cement is heavy; blue gray, slow-setting. Quick-setting has generally too much clay in its composition—is brownish and weak.
6. Less water used in mixing cement the better.
7. Bricks, stones, etc., used with cement should be well wetted before use.
8. Cement setting under *still* water will be stronger than if kept dry.
9. Bricks of neat Portland cement in a few months are equal to Blue brick, Bramley-Fall stone, or Yorkshire landings.
10. Bricks of 1 cement to 4 or 5 of sand are equal to picked stock bricks.
11. When concrete is being used, a current of water will wash away the cement.

Artificial Cement is made by a combination of slaked lime with unburnt clay in suitable proportions.

Artificial Pozzuolana is made by subjecting clay to a slight calcination.

Salt water has a tendency to decompose cements of all kinds, and their strength is considerably impaired by their mixture with it.

Mortar.

Lime or Cement paste is the cementing substance in mortar, and its proportion should be determined by the rule that *Volume of cementing substance should be somewhat in excess of volume of voids or spaces in sand or coarse material to be united,* the excess being added to meet imperfect manipulation of the mass.

Hydraulic Mortar, if re-pulverized and formed into a paste after having once *set,* immediately loses a great portion of its hydraulicity, and descends to the level of moderate hydraulic limes.

The retarding influence of sea-water upon initial hydraulic induration is not very great, if the cement is mixed with fresh water. The strength of mortars, however, is considerably impaired by being mixed with sea-water.

Pointing Mortar is composed of a paste of finely-ground cement and sharp siliceous sand, in such proportions that the volume of cement is slightly in excess of the volume of voids or spaces in the sand. The

nd varies from 2.5 to 2.75 that of the cement paste, or by weight, 1 of :nt powder to 3 to 3.33 of sand. The mixture should be made under er, and in small quantities.

mortars are much improved by being worked or manipulated; and as rich : gain somewhat by exposure to the air, it is advisable to work mortar in quantities, and then render it fit for use by a second manipulation.

ıite lime will take a larger proportion of sand than brown lime.

; of salt-water in the composition of mortar injures adhesion of it.

hen a small quantity of water is mixed with slaked lime, a stiff paste ıde, which, upon becoming dry or hard, has but very little tenacity, but, eing mixed with sand or like substance, it acquires the properties of a nt or mortar.

oportion of sand that can be incorporated with mortar depends partly the degree of fineness of the sand itself, and partly upon character of ime. For rich limes, the resistance is increased if the sand is in pro- ons varying from 50 to 240 per cent. of the paste in volume; beyond proportion the resistance decreases.

me, 1, clean sharp sand, 2.5. An excess of water in slaking the lime s the mortar, which remains light and porous, or shrinks in drying; an ss of sand destroys the cohesive properties of the mass.

s indispensable that the sand should be sharp and clean.

me Mortar.—8 parts cement, 3 parts lime, and 31 parts of sand; or 1 cement, 325 lbs., .5 cask of lime, 120 lbs., and 14.7 cube feet of sand= cube feet of mortar.

ick Mortar.—8 parts cement, 3 parts lime, and 27 parts of sand; or 1 cement, 325 lbs., .5 cask of lime, 120 lbs., and 12 cube feet of sand= ıbe feet of mortar.

own Mortar.—Lime 1 part, sand 2 parts, and a small quantity of hair.

ne and sand, and cement and sand, lessen about .33 in volume when mixed her.

ılcareous Mortar, being composed of one or more of the varieties of lime :ment, natural or artificial, mixed with sand, will vary in its properties quality of the lime or cement used, the nature and quality of sand, and ıod of manipulation.

Turkish Plaster, or Hydraulic Cement.

ɔ lbs. fresh lime reduced to powder, 10 quarts linseed-oil, and 1 to 2 ɜs cotton. Manipulate the lime, gradually mixing the oil and cotton, in oden vessel, until mixture becomes of the consistency of bread-dough.

r, and when required for use, mix with linseed-oil to the consistency of paste, hen lay on in coats. Water-pipes of clay or metal, joined or coated with it, the effect of humidity for very long periods.

Stucco.

ucco or Exterior Plaster is term given to a certain mo· ed for :ior plastering; it is sometimes manipulated to res· rated ıle, and consists of 1 volume of cement powder to 2 vol

India, to water for mixing the plaster is added 1 lb. ‹ › *8 Imperial gallons of* water, for the first coat; and fo *lb. sugar to 2 gallons* of water.

dered slaked lime and Smith's forge scales, mixed w *oportions, make* a moderate hydraulic mortar, which *r previously coated* with boiled oil.

Plaster should be applied in two coats laid on in one operation, first coat bei thinner than second. Second coat is applied upon first while latter is yet soft.

The two coats should form one of about 1.5 inches in thickness, and when fi ished it should be kept moist for several days.

When the cement is of too dark a color for desired shade, it may be mixed wi white sand in whole or in part, or lime paste may be added until its volume equ that of the cement paste.

Khorassar, or Turkish Mortar,

Used for the construction of buildings requiring great solidity, .33 pow dered brick and tiles, .66 fine sifted lime. Mix with water to required con sistency, and lay between the courses of brick or stones.

Mortars.

Mortars used for inside plastering are termed Coarse, Fine, Gauge or hard finish, and Stucco.

Plastering.—1 bushel, or 1.25 cube feet of cement, mortar, etc., will cover 1.5 square yards .75 inch thick. 75 volumes are required upon brick work for 70 upon laths.

When full time for hardening cannot be allowed, substitute from 15 to 20 per cent. of the lime by an equal proportion of hydraulic cement.

For the second or *brown coat* the proportion of hair may be slightly diminished.

Coarse Stuff.—Common lime mortar, as made for brick masonry, with a small quantity of hair; or by volumes, lime paste (30 lbs. lime) 1 part, sand 2 to 2.25 parts, hair .16 part.

Fine Stuff (lime putty).—Lump lime slaked to a paste with a mod erate volume of water, and afterwards diluted to consistency of cream, and then to harden by evaporation to required consistency for working.

In this state it is used for a *slipped coat*, and when mixed with sand or plaster of Paris, it is used for *finishing coat.*

Gauge, or Hard Finish, is composed of from 3 to 4 volumes fine stuff and 1 volume plaster of Paris, in proportions regulated by rapidity re quired in hardening; for cornices, etc., proportions are equal volumes of each, fine stuff and plaster.

Scratch Coat.—First of three coats when laid upon laths, and is from .25 to .375 of an inch in thickness.

One-coat Work.—Plastering in one coat without finish, either on masonry or laths—that is, *rendered* or *laid.*

Two-coat Work.—Plastering in two coats is done either in a *laid coat* ...*nd set*, or in a *screed coat and set.*

...*eed coat* is also termed a *Floated coat. Laid* first coat in two-coat ...is resorted to in common work instead of *screeding*, when finished sur... not required to be exact to a straight-edge. It is laid in a coat of .5 inch in thickness.

...d coat, except for very common work, should be *hand-floated.*

...ess and tenacity of plastering is very much increased by hand-floating.

...*ds* are strips of mortar 6 to 8 inches in width, and of required thick... first coat, applied to the angles of a room, or edge of a wall and para... at intervals of 3 to 5 feet over surface to be covered. When these have ...me sufficiently hard to withstand pressure of a straight-edge, the inter... ...tween the screeds are filled out flush with them.

... smoothing off of a brown coat with a small quantity ... 3 per cent. of white sand, so as to make a comp...

... to be finished in distemper, or p...

Concrete or Beton

ıixture of mortar (generally hydraulic) with coarse materials, as pebbles, stones, shells, broken bricks, etc. Two or more of these ıls, or all of them, may be used together. As lime or cement paste is ıenting substance in mortar, so is mortar the cementing substance in e or beton. The original distinction between cement and beton was, :ter possessed hydraulic energy, while former did not.

·aulic.—1.5 parts unslaked hydraulic lime, 1.5 parts sand, 1 part and 2 parts of a hard broken limestone.

nass contracts one fifth in volume. Fat lime may be mixed with concrete, serious prejudice to its hydraulic energy.

Various Compositions of Concrete.

·aulic.—308 lbs. cement = 3.65 to 3.7 cube feet of stiff paste. 12 cube loose sand = 9.75 cube feet of dense.

Superstructure.—11.75 cube feet of mortar as above, and 16 cube feet e fragments.

Wall.—Boston Harbor.—Hydraulic.—308 lbs. cement, 8 cube feet of nd 30 cube feet of gravel. Whole producing 32.3 cube feet.

·rstructure.—308 lbs. cement, 80 lbs. lime, and 14.6 cube feet dense Whole producing 12.825 cube feet.

ə is made of clay or earth rammed in layers of from 3 to 4 ins. in depth. In limates, it is necessary to protect the external surface of a wall constructed manner with a coat of mortar.

Asphalt Composition.

neral pitch 1 part, bitumen 11, powdered stone, or wood ashes, 7 parts.

hes 2 parts, clay 3 parts, and sand 1 part, mixed with a little oil, makes a e and durable cement, suitable for external use.

ing.—8 lbs. of composition will cover 1 sup. foot, .75 inch thick.

ıltum 55 lbs. and gravel 28.7 lbs. will cover an area of 10.75 sq. feet.

stic. — Pulverized burnt clay 93 parts, litharge, ground very fine, 7 parts, vith a sufficient quantity of pure linseed oil.

ceous sand 14, pulverized calcareous stone 14, litharge 2, and linseed oil 4 weight.

owders to be well dried in an oven, and the surface upon which it is to be must be saturated with oil.

Roads.—Bitumen 16.875 parts, asphaltum 225 parts, oil of resin 6.25 parts, d 135 parts. Thickness, from 1.25 to 1.375 ins.

cial Mastic.—Composition of 1 square yard .9 inch thick:

ıeral tar	205 cube ins.	Gravel	275 cube ins.
:h	165 " "	Slaked lime	55 " "
d	549 " "		1249 cube ins.

ral Efflorescence.—White alkaline efflorescence upon the surface walls laid in mortar, of which natural hydraulic lime or cement is the basis .r mixed with animal fat in the proportion of .025 of its weight ation.

allization of these salts within the pores of bricks, into whi sorbed from the mortar, causes disintegration.

:mper is term for all coloring mixed with water and size.

ting.—Mortar composed of lime and fine sand, in a sem into the *upper beds* and *internal* joints of masonry.

:nce is the pulpy and gelatinous fluid, of a milky hue, tha *ıent upon its being* deposited in water. It is produced *sea water than* in fresh; it sets very imperfectly, and *essen the strength of the* concrete.

Slaking.

Slaked Lime is a hydrate of lime, and it absorbs a mean of 2.5 times its volume, and 2.25 times its weight of water.

Lime (*quicklime*) must be slaked before it can be used as a matrix for mortar.

Ordinary method of slaking is by submitting the lime to its full proportion of water (previously known or attained by trial) in order to reduce it to the consistency of a thick pulp. The volume of water required for this purpose will vary with different limes, and will range from 2.5 to 3 volumes that of the lime, and it is imperative that it should all be poured upon it so nearly at one time as to be in advance of the elevation of the temperature consequent upon its reduction.

This process, when the water used is in an excessive quantity, is termed "drowning," and when the volume of lime has increased by the absorption of water it is termed its "growth."

If too much water is used, the binding qualities of the lime is injured by its semi-fluidity; and if too little, it is injurious to add after the reduction of the lime has commenced, as it reduces its temperature and renders it granular and lumpy.

While lime is in progress of slaking it should be covered with a tarpaulin or canvas (a layer of sand will suffice), in order to concentrate its evolved heat.

The essential point in slaking is to attain the complete reduction of the lime, and the greater the hydraulic energy of a lime, the more difficult it becomes to effect it.

Whitewash or Grouting.—When lime is required for a whitewash or for grouting, it should be thoroughly "drowned," and then run off into tight vessels and closed.

Slaking by Immersion is the method of suspending lime in a suitable vessel in water for a very brief period, and withdrawing it before reduction commences. The lime is then transferred to casks or like suitable receptacles and tightly enclosed, until it is reduced to a fine powder, in which condition if secured from absorption of air, it may be preserved for several months without essential deterioration.

Spontaneous or Air Slaking.—When lime is not wholly secured from exposure to the air, it absorbs moisture therefrom, slakes, and falls into a powder.

Limes and Cements.—A Cask of Lime = 240 lbs., will make from 7.8 to 8.15 cube feet of stiff paste.

A Cask of Cement = 300* lbs., will make from 3.7 to 3.75 cube feet of stiff paste.

A Cask of Portland Cement = 4 bushels or 5 cube feet = 420 lbs.

A Cask of Roman Cement = 3 bushels or 3.75 cube feet = 364 lbs.

	.5 inch.	.75 inch.	1 inch.
A Bushel of cement will cover.......	2.25 yards	1.5 yards	1.14 yards

From experiments of General Totten, it appeared that

1	volume of lime slaked with	.33	its volume of water	gave	2.27	volumes of paste
1	"	"	"	.66	"	"	1.74	"
1	"	"	"	1	"	"	2.06	"

One cube foot of dry cement, mixed with .33 cube foot of water, will make .6 to .635 cube foot of stiff paste.

Lime should be slaked at least one day before it is incorporated with ... and when they are thoroughly mixed, the mortar should be kept in a ... or mass, for use as required.

* 300 lbs. net is standard; it usually overruns 8 lbs.

Mortar, Cement, &c. (*Molesworth.*)

fortar.—1 of lime to 2 to 3 of sharp river sand.
ʳr, 1 of lime to 2 sand and 1 blacksmith's ashes, or coarsely ground coke.

'oarse Mortar.—1 of lime to 4 of coarse gravelly sand.

'oncrete.—1 of lime to 4 of gravel and 2 of sand.

Iydraulic Mortar.—1 of blue lias lime to 2.5 of burnt clay, ground to-
ıer.
ɔr, 1 of blue lias lime to 6 of sharp sand, 1 of pozzuolana and 1 of calcined
ıstone.

Ɔeton.—1 of hydraulic mortar to 1.5 of angular stones.

'ement.—1 of sand to 1 of cement.—If great tenacity is required, the ce-
ıt should be used without sand.

Portland Cement

ɔomposed of clayey mud and chalk ground together, and afterwards cal-
ɔd at a high temperature—after calcining it is ground to a fine powder.

Strength of Mortars, Cements, and Concretes.

Deduced from Experiments of Vicat, Paisley, Treussart, and Voisin.

Tensile

Weight or Power required to Tear asunder One Sq. Inch.

Cement Mortar. (42 *days old.*)

	Proportion of Sand to 1 of Cement.										
	0	1	2	3	4	5	6	7	8	9	10
ıan.......	284	284	199	166	142	128	116	106	99	92	95 lbs.
land.....	142	142	113	92	79	67	57	42	35	25	— "

Brick, Stone, and Granite Masonry. (320 *days old.*)

Experiments of General Gillmore, U. S. A.

'ement on Bricks.

	Lbs.
, average	30.8
· 1 / ent 1	15.7
· 1 / ent 2	12.3
· 1 / ent 3	6.8

Cement on Granite.

	Lbs.
Pure................	27.5
Sand 1 / Cement 1	20.8
Sand 1 / Cement 2	12.6
Sand 1 / Cement 3	9.2

	Lbs.
Sand 1 / Cement 4	7.9
Water 1 / Cement 2	20.5
Water .42 / Cement 1	37.25
Water .33 / Cement 1	29.15

field and Baxter.	Lbs.
ıre cement........	68
ment 4 / nd 1	68
ment 8 / ftings 1	80
ment 1 / ftings 1	82
ment 1 / *ings 2*	*74*
ence Cement Co.	
cement	*87*
"	*54*

James River.	Lbs.
Pure cement........	87
Cement 4 / Sand 1	62
Newark Lime and Cement Co.	
Pure cement........	93
Cement 1 / Sand 2	40
Newark and Rosendale.	
Pure cement........	75
Cement 1 / Sand 1	16

	Lbs.
Newark and Rosendale.	
Cement 1 / Sand 3	7
Pure, without / mortar, mean	45

Mort

Lime paste 1,
" " 1
" "
" "
cement pa

Pure Cement.

	Lbs.		
Boulogne 100, water 50	112	Portland, in sea-water, 45 days	[illegible]
Portland, natural, 1 year	675	" English, 6 months	[illegible]
" artificial, Eng., 1 year	462	Roman "Septaria," 1 year	[illegible]
" English, 320 days	1152	" masonry, 5 months	[illegible]
" " 1 month	393	Rosendale, 9 months	[illegible]
Newark and Rosendale	339	Lawrence Cement Co.	[illegible]

Transverse.

Reduced to a uniform Measure of One Inch Square and One Foot in L[illegible] Supported at Both Ends.

Experiments of General Gillmore.

Formed in molds under a pressure of 32 lbs. per sq. inch, applied until m[illegible] had set. Exposed to moisture for 24 hours, and then immersed in sea-water.

Prisms 2 by 2 by 8 ins. between supports.

Reduced by Formula $\frac{2}{3}\,\frac{l\,W}{4\,b\,d^2} - \frac{a}{2} = C$. *C coefficient of rupture, and a* [illegible] *portion of prism l.*

Cement. *Mortar.*

Material.	Age.	Pure.	Material.	Age.	Cement [illegible] Sand [illegible]
	Days.	Lbs.		Days.	Lbs.
James River.			Portland, Eng., stiff paste	320	13
Thick cream	59	3.9	Roman, " " "	20	2.5
Thin paste	320	5.8	" " " "	100	6
Stiff paste	59	6.9	Cumberland, Md.	320	12.8
Rosendale "Hoffman."			Akron, N. Y.	320	8.8
Thin paste	320	9	James River, Va.	320	8.6
Stiff paste	320	8.9	Pulverized and re-mixed after set	3	3.6
"Delafield and Baxter."					
Thin paste	320	8.5	Fresh	320	9
Stiff paste	320	12	Kingston and Rosendale.	320	7.6
English.			High Falls, Ulster Co., N.Y.	95	—
Portland, pure	320	16			
Stiff paste	320	13	Fresh water to a stiff paste	95	—
Cumberland, Md., pure	320	13.2			
High Falls, Ulster Co., N. Y.	95	8.4	Sea-water to a stiff paste	95	—
			Lawrence Cement Co.		
Complete calcination	95	4.2	Fresh	320	10.2

Crushing.

Cements, Stones, etc. (*Crystal Palace, London.*)

Reduced to a uniform Measure of One Sq. Inch.

Material.	Destructive Pressure.	Material.	Destructive Pressure.
	Lbs.		Lbs.
Portl'd cem't, area 1, height 1.	1680	Portland cement 1, " sand 4	[illegible]
" cement, " sand	1244	" cement 1, " sand 7	[illegible]
" stone	1144	Roman cement, pure	[illegible]

General Deductions.

1. Particles of unground cement exceeding .0125 of an inch in diamete[illegible] allowed in cement paste without sand, to extent of 50 per cent. of wh[illegible] detriment to its properties, while a corresponding proportion of sand [illegible] strength of mortar about 40 per cent.

ıen these unground particles exist in cement paste to extent of 66 per cent. e, adhesive strength is diminished about 28 per cent. For a corresponding ion of sand the diminution is 68 per cent.

dition of siftings exercises a less injurious effect upon the cohesive than upon esive property of cement. The converse is true when sand, instead of sift- used.

all mixtures with siftings, even when the latter amounted to 66 per cent. of cohesive strength of mortars exceeded their adhesion to bricks. Same re- ıpear to exist when siftings are replaced by sand, until volume of the latter ; 20 per cent. of whole, after which adhesion exceeds cohesion.

age of 320 days (and perhaps considerably within that period) cohesive h of pure cement mortar exceeds that of Croton front bricks. The converse when the mortar contains 50 per cent. or more of sand.

ıen cement is to be used without sand, as may be the case when *grouting* is 1 to, or when old walls are to be repaired by injections of thin paste, there is ıntage in having it ground to an impalpable powder.

r economy it is customary to add lime to cement mortars, and this may be ɔ a considerable extent when in positions where hydraulic activity and h are not required in an eminent degree.

mming of concrete under water is held to be injurious.

ırtars of common lime, when suitably made, *set* in a very few days, and with pidity that there is no need of awaiting its hardening in the prosecution of

e Clay.—The fusibility of clay arises from the presence of impurities, lime, iron, and manganese. These may be removed by steeping the clay in riatic acid, then washing it with water. Crucibles from common clay may e in this manner.

s by General Gillmore, U. S. A.—Recent experiments have developed that merican cements will sustain, without any great loss of strength, a dose of ıste equal to that of the cement paste, while a dose equal to 5 to 75 the vol- cement paste may be safely added to any Rosendale cement without pro- any essential deterioration of the quality of the mortar. Neither is the lic activity of the mortars so far impaired by this limited addition of lime ıs to render them unsuited for concrete under water, or other submarine y. By the use of lime is secured the double advantages of slow setting and ıy.

s by General Totten, U. S. A.—240 lbs. lime = 1 cask, will make from 7.8 to be feet of stiff paste.

ɔe foot of dry cement powder, measured when loose, will measure .78 to .8 ıot when packed, as at a manufactory.

composition of Concretes, at Toulon, Marseilles, Cherbourg, Dover, Alderney, e Treatise of General Gillmore, pp. 253–256.

MASONRY.

Brickwork.

ıd is an arrangement of bricks or stones, laid aside of and above ɔther, so that the vertical joint between any two bricks or stones ıot coincide with that between any other two.

is termed "breaking joints."

der is a brick or stone laid with an end to face of wall.

tcher is a brick or stone laid parallel to face of wall.

der Course or *Bond* is a course or courses of headers alone.

tcher Course or *Bond* is a course or courses of stretche

ers are pieces of bricks inserted in alternate courses, i by preventing two headers from being exactly over

ish Bond is laying of headers and stretchers in alte

Flemish Bond is laying of headers and stretchers alternately in each course.

Gauged Work.—Bricks cut and rubbed to exact shape required.

String Course is a horizontal and projecting course around a building.

Corbelling is projection of some courses of a wall beyond its face, in order to support wall-plates or floor-beams, etc.

Wood Bricks, *Pallets*, *Plugs*, or *Slips* are pieces of wood laid in a wall in order the better to secure any woodwork that it may be necessary to fasten to it.

Reveals are portions of sides of an opening in a wall in front of the recess for a door or window frame.

Brick Ashlar.—Walls with ashlar-facing backed with brick.

Grouting is pouring liquid mortar over last course for the purpose of filling all vacuities.

Larrying is filling in of interior of thick walls or piers, after exterior faces are laid, with a bed of soft mortar and floating bricks or spawls in it.

Rendering (Eng.) is application of first coat on masonry, *Laying* if one or two coats on laths, and "Pricking up" if three-coat work on laths.

Bricks should be well wetted before use. *Sea sand* should not be used in the composition of mortar, as it contains salt and its grains are round, being worn by attrition, and consequently having less tenacity than sharp-edged grains.

A common burned brick will absorb 1 pint or about one sixth of its weight of water to saturate it. The volume of water a brick will absorb is inversely a test of its quality.

A good brick should not absorb to exceed .067 of its weight of water.

The courses of brick walls should be of same height in front and rear, whether front is laid with stretchers and thin joints or not.

In ashlar-facing the stones should have a width or depth of bed at least equal to height of stone.

Hard bricks set in cement and 3 months set will sustain a pressure of 40 tons per sq. foot.

The compression to which a stone should be subjected should not exceed .1 of its crushing resistance.

The extreme stress upon any part of the masonry of St. Peter's at Rome is computed at 15.5 tons per sq. foot; of St. Paul's, London, 14 tons; and of piers of New York and Brooklyn Bridge, 5.5 tons.

The absorption of water in 24 hours by granites, sandstones, and limestones of durable description is 1, 8, and 12 per cent. of volume of the stone.

Color of Bricks depends upon composition of the clay, the molding sand, temperature of burning, and volume of air admitted to kiln.

Pure clay free of iron will burn *white*, and mixing of chalk with the clay will produce a like effect.

Presence of iron produces a tint ranging from *red* and *orange* to *light yellow*, according to proportion of iron.

A large proportion of oxide of iron, mixed with a pure clay, will produce a bright *red*, and when there is from 8 to 10 per cent., and the brick is exposed to an intense heat, the oxide fuses and produces a *dark blue* or *purple*, and with a small volume of manganese and an increased proportion of the oxide the color is darkened, even to a *black*.

Small volume of lime and iron produces a *cream color*, an increase of iron produces *red*, and an increase of lime *brown*.

Magnesia in presence of iron produces *yellow*.

Clay containing alkalies and burned at a high temperature produces a *bluish green*.

For other notes on materials of masonry, their manipulation, etc., see "Limes, Cements, Mortars, and Concretes," pp. 588–597.

Pointing.—Before pointing, the joints should be reamed, and in clean ... they must be open to 2 of an inch, then thoroughly saturated with water ... maintained in a condition that they will neither absorb water from the mortar ... any to it. Masonry should not be allowed to dry rapidly after pointing ... --ll driven in by the aid of a calking iron and hammer. ... masonry the same general directions are to be observed.

rgillaceous, *Siliceous*, or *Calcareous*, according to its composition. revent excessive shrinking, and to save cost of lime or cement. Or- ot acted upon by lime, its presence in mortar being mechanical, and limes and cements it weakens the mortar. Rich lime adheres better of sand than to its own particles; hence the sand strengthens the

tive that sand should be perfectly clean, freed from all impurities. p or angular structure. Within moderate limits size of grain does strength of mortar; preference, however, should be given to coarse. and is preferable to siliceous.
er sand are suitable for plastering, but are deficient in the sharpness ortar, from the attrition they are exposed to.
vill not soil the hands when rubbed upon them, and the presence of ected by its taste.
, Clinker, and Cinder, when properly crushed and used, make good sand.

n the mixing of concrete, slake lime first, mix with cement, and then , etc., deposit in layers of 6 ins., and hammer down.

Bricks.

in dimensions by various manufacturers, and different degrees f their burning, render a table of exact dimensions of different s and classes of bricks altogether impracticable.

onent, however, of the ranges of their dimensions, following given:

.	Ins.	Description.	Ins.
ont	8.25 × 4.125 × 2.375	Maine	7.5 × 3.375 × 2.375
"		Milwaukee	8.5 × 4.125 × 2.375
"		North River	8 × 3.5 × 2.25
"	8.5 × 4 × 2.25	Ordinary	7.75 × 3.625 × 2.25
...	8.25 × 3.625 × 2.375		8 × 4.125 × 2.5
...	9 × 4.5 × 2.5	Stourbridge fire-brick	9.125 × 4.625 × 2.375
ock	8.75 × 4.25 × 2.5		
...	6.25 × 3 × 1.5	Amer. do., N. Y.	8.875 × 4.5 × 2.625

ence of the variations in dimensions of bricks, and thickness of mortar or cement in which they may be laid, it is also impracti- any rule of general application for volume of laid brick-work. ecessary, therefore, when it is required to ascertain the volume masonry, to proceed as follows:

ute Volume of Bricks, and Number in a Cube Foot of Masonry.

o face dimensions of particular bricks used, add one half thick- nortar or cement in which they are laid, and compute the area; of wall by number of bricks of which it is composed; multiply quotient thus obtained, and product will give volume of the ick and its mortar in ins.
28 by this volume, and quotient will give number of bricks in a

-Width of a wall is to be 12.75 ins., and front of it la... Philadel- n courses .25 of an inch in depth; how many brick ... he in ing in a cube foot?

a front brick, 8.25 × 2.375 ins. face.

$\overline{.25 \times 2 \div 2} = 8.25 + .25 = 8.5$ = *length of bric*

$\overline{.25 \times 2 \div 2} = 2.375 + .25 = 2.625$ = *width of brick*

$.625 = 22.3125$ *ins.* = *area of face*; $12.75 \div 3$ (nu...
$= 4.25$ *ins.*

$\times 4.25 = 94.83$ *cube ins.*; and $1728 \div 94.83 = 18.2$...

One rod of brick masonry (Eng.) = 11.33 cube yards and weighs 15 to[ns] [illegible] superficial feet [illegible] thick, averaging 4500 bricks, requiring 3 cube yard[s] [illegible] and 100 gallons water.

Bricklayers' hod will contain 20 bricks or .7 cube feet mortar.

Fire-bricks.

Fire-clay contains Silica, Alumina, Oxide of Iron, and a small pr[oportion] of Lime, Magnesia, Potash, and Soda. Its fire-resisting properties [depend]ing upon the relative proportions of these constituents and charact[er of] grain.

A good clay should be of a uniform structure, a coarse open grai[n] [illegible] to the hand, and free from any alkaline earths.

The Stourbridge clay is black and is composed as follows:

Silica......65.1 | Alumina...... 22.2 | Lime......73 | Protoxide of iro[n] [illegible]
Water and organic matter........ 10.3

Newcastle clay is very similar.

Thickness of Brick Walls for Warehouses in [illegible]
(Holmsworth.)

Height in Feet	100	90	80	70	60	50	40	3[illegible]
Length Unlimited	—	—	—	—	—	—	—	[illegible]
Thickness in Ins.	34	34	30	26	26	26	21.5	1[illegible]
Length in Feet	70	70	60	45	50	70	60	5[illegible]
Thickness in Ins.	30	30	26	21.5	21.5	21.5	17.5	[illegible]
Length in Feet	55	60	45	30	35	40	30	4[illegible]
Thickness in Ins.	26	26	21.5	17.5	17.5	17.5	13	1[illegible]

Stone Masonry.

Masonry is classed as *Ashlar* or *Rubble*.

Ashlar is composed of blocks of stone dressed square and la[id in] close joints.

Coursed Ashlar consists of blocks of same height throughout each [course].

Rubble Ashlar

Is ashlar faced stone with rubble backing.

Fig. 1.

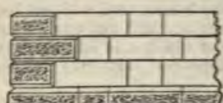


Fig. 1.—*Coursed*, with chamfered and rusticated quoins and plinth.

Fig. 2.

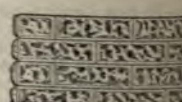


Fig. 2.—*Coursed*, with rock f[ace and] draft edges.

Fig. 3.

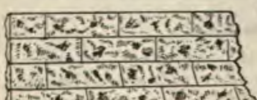


Fig. 3.—*Coursed*, with rock face.

Fig. 4.

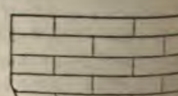


Fig. 4.—Regular Cou[rsed]

Rubble Masonry

npposed of small stones irregular in form, and rough.

Fig. 6.

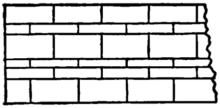


Fig. 5.—*Irregular Coursed.*

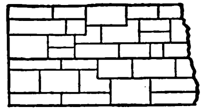
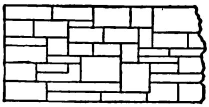


Fig. 6.—*Random Coursed.*

7.



7.—*Ranged Random*, level, and n courses.

Fig. 8.

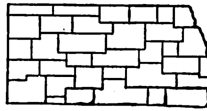
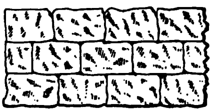


Fig. 8.—*Random*, level, and broken.



. 9. *Block Coursed.*—Large blocks urses (regular or irregular), Beds oints roughly dressed.

Fig. 10.

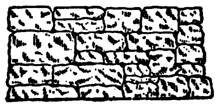
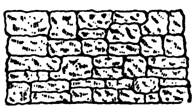


Fig. 10.—*Coursed and Ranged Random.*

1.



. 11. *Ranged Random.*—Squared ɜ laid in level and broken es.

Fig. 12.

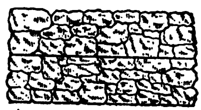
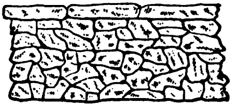


Fig. 12. *Coursed Random.*—Stones laid in courses at intervals of from 12 to 18 ins. in height.

Dry Rubble

vall laid without cement or mortar.

3.



. 13. *Dry Rubble.*—Without mor- cement.

Fig. 14.

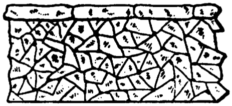


Fig. 14. *Rustic or Rag.*—Stones of irregular form, and dressed to make close joints.

5.

. 15. *Uncoursed or Random.*— ınd Joints undressed, projections d off, and laid at random. In- s filled with spalls and mortar.

Fig. 16.

Fig. 16. Laced bands of stone or give stability.

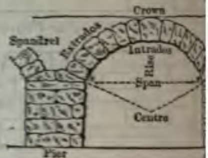
—*Rustic or Rag* work is frequently laid in mortar.

Terra Cotta.

Terra Cotta in blocks should not exceed 4 cube feet in volume. properly burned, it is unaffected by the atmosphere or by fumes of an

Arches and Walls.

Springing.—Point *s*, Fig. 15, on each side, from which arch springs.



Crown.—Highest point of arch.

Haunches.—Sides of arch, from springing half-way up to crown.

Spandrel.—Space between extrados, a horizontal line drawn through crown and a vertical line through upper end of skewback.

Skewback is upper surface of an abutment or pier from which an arch springs, and its face is on a line radiating from centre of arch.

Abutment is outer body that supports arch and from which it sprin

Pier is the intermediate support for two or more arches.

Jambs are sides of abutments or piers.

Voussoirs are the blocks forming an arch.

Key-stone is centre voussoir at crown.

Span is horizontal distance from springing to springing of arch.

Rise.—Height from springing line to under side of arch at key-sto

Length is that of springing line or span.

Ring-course of a wall or arch is parallel to face of it, and in direc its span.

String and Collar courses are projecting ashlar dressed broad st right angles to face of a wall or arch, and in direction of its length.

Camber is a slight rise of an arch as .125 to .25 of an inch per span.

Quoin is the external angle or course of a wall.

Plinth is a projecting base to a wall.

Footing is projecting course at bottom of a wall, in order to distri weight over an increased area. Its width should be double that of wall, diminishing in regular offsets .5 width of their height.

Blocking Course.—A course placed on top of a cornice.

Parapet is a low wall, over edge of a roof or terrace.

Extrados.—Back or upper and outer surface of an arch.

Intrados or *Soffit* is underside of lower surface of arch or an openi

Groined is when arches intersect one another.

Invert.—An inverted arch, an arch with its intrados below axis or ing line.

Ashlar masonry requires .125 of its volume of mortar. *Rubble,* 1. yards stone and .25 cube yard mortar for each cube yard.

Rubble masonry in cement, 160 feet in height, will stand and bear lbs. per sq. inch.

Stones should be laid with their strata horizontal.

When "through" or "thorough bonds" are not introduced, headers overlap one another from opposite sides, known as *dogs' tooth bond.*

Aggregate surface of ends of bond stones should be from .125 to area of each face of wall.

Weak stones, as sandstone and granular limestone, should not h length over 3 times their depth. Strong or hard stones may have from 4 to 5 times their depth.

Gallets are small and sharp pieces of stone stuck into mortar joints, i which case the work is termed *galleted.*

Snapped work is when stones are split and roughly squared.

Quarry or Rock-faced.—Quarried stones with their faces undressed.

Pitch-faced.—Stones on which the arris or angles of their face, with thei sides and ends, is defined by a chisel, in order to show a right-lined edge.

Drafted or Drafted Margin is a narrow border chiselled around edges c faces of a block of rough stone.

Diamond-faced is when planes are either sunk or raised from each edg and meet in the centre.

Squared Stones.—Stones roughly squared and dressed.

Rubble.—Unsquared stones, as taken from a quarry or elsewhere, in thei natural form, or their extreme projections removed.

Cut Stones.—Stones squared and with dressed sides and ends.

Dressed Stones.

The following are the modes of dressing the faces of ashlar in engineering

Rough Pointed.—Rough dressing with a pick or heavy point.

Fine Pointed.—Rough dressing, followed by dressing with a fine point.

Crandalled.—Fine pointing in right lines with a hammer, the face o which is close serried with sharp edges.

Cross Crandalled.—When the operation of crandalling is right angled.

Hammered.—The surface of stone may be finished or smooth dressed b being *Axed* or *Bushed;* the former is a finish by a heavy hammer alike to crandall, the latter is a final finish by a heavy hammer with a face serrie with sharp points at right angles.

Thickness of Brick Walls for Warehouses. (*Molesworth.*)

Length.	Height.	Thickness.	Length.	Height.	Thickness.	Length.	Height.	Thicknes
Feet.	Feet.	Ins.	Feet.	Feet.	Ins.	Feet.	Feet.	Ins.
Unlimited.	25	13	Unlimit'd.	100	34	45	30	13
do.	30	17.5	60	40	17.5	30	40	13
do.	40	21.5	70	50	21.5	40	50	17.5
do.	50	26	50	60	21.5	35	60	17.5
do.	60	26	45	70	21.5	30	70	17.5
do.	70	26	60	80	26	45	80	21.5
do.	80	30	70	90	30	60	90	26
do.	90	34	70	100	30	55	100	26

For drawings and a description of stone-dressing tools, see a paper by J. R. Cross W. E. Merrill, and E. B. Van Winkle, "A. S. Civil Engineer Trans ... 1877

Walls not exceeding 30 feet in height, upper story walls may b

From 16 feet below top of wall to base of it, it should not be l defined by two right lines drawn from each side of wall at its b top.

Thickness not to be less in any case than one fourteenth of he

Laths.

Laths are 1.25 to 1.5 ins. by 4 feet in length, are usually se *part, and a bundle contains 100.*

Plastering.

Volumes required for Various Thickness.

Material.	Square Yards. .5	.75	1	Material.	Square Yards. .5	.75	1
Cube Feet.	Ins.	Ins.	Ins.	Cube Feet.	Ins.	Ins.	Ins.
Cement 1..........	2.25	1.5	1.15	Lime 1, sand 2, hair 3.75......	75 yards, sup'l rendered and set on brick or 70 on lath		
Cement 1, sand 1...	4.5	3	2.25				
Cement 1, sand 2...	6.75	4.5	3.33				

Estimate of Materials and Labor for 100 Sq. Yards of Lath and Plaster.

Materials and Labor.	Three Coats Hard Finish.	Two Coats Slipped.	Materials and Labor.	Three Coats Hard Finish.	Two Coats Slipped.
Lime...........	4 casks.	3.5 casks.	White sand....	2.5 bushels.	
Lump lime	.66 "		Nails	13 lbs.	13 lbs.
Plaster of Paris..	.5 "		Masons	4 days.	3.5 days.
Laths...........	2000.	2000.	Laborer.......	3 "	2 "
Hair............	4 bushels.	3 bushels.	Cartage.......	1 "	.75 "
Sand	7 loads.	6 loads.			

Rough Cast is washed gravel mixed with hot hydraulic lime and water and applied in a semi-fluid condition.

Arches and Abutments.

To Compute Depth of Keystone of Circular or Elliptic Arch.

$\frac{\sqrt{R + s \div 2}}{4} + .25 = d.$ R *representing radius, s span, and d depth, all in feet.*

This is for a rise of about .25 of span; when it is reduced, as to .125, add .5 instead of .25.

Illustration.—Arch of Washington aqueduct at "Cabin John" has a span of 220 feet, a rise of 57.25, and a radius of 134.25; what should be depth of its keystone?

$$\frac{\sqrt{134.25 + 220 \div 2}}{4} + .25 = \frac{15.63}{4} + .25 = 4.16 \textit{ feet.}$$ Depth is 4.16 feet.

Viaducts of several arches increase results as determined above by adding .125 to .15 to depth.

For arches of 2d class materials and work, and for spans exceeding 50 feet, add .125 to depth of keystone, and for good rubble or brick-work add .25.

Note.—It is customary to make the keystones of elliptic arches of greater depth than that obtained by above formula. Trautwine, however, who is high authority in this case, declares it is unnecessary.

To Compute Radius of an Arch, Circular or Ellipse.

$$\left(\frac{s}{2}\right)^2 + r^2 \div 2\,r = R. \quad r \textit{ representing rise.}$$

Railway Arches.

For Spans between 25 and 70 feet. Rise .2 of span. Depth of arch .055 of span. Thickness of abutments .2 to .25 of span, and of pier .14 to .16 of span.

Abutments.

...height does not exceed 1.5 times base. R ÷ 5 + .1 r + 2 = thickness of ... (*Trautwine.*)

... 1.5 ins. per foot of height of wall.

To Compute Depth of Arch. (*Hurst.*)

$c\sqrt{R} = D$. c = Stone (block) .3. Brick = .4. Rubble = .45.

:n there are a series of arches, put .3 = .35, .4 = .45, and .45 = .5.

nimum Thickness of Abutments for Bridge and similar Arches of 120°. (*Hurst.*)

en depth of crown does not exceed 3 *feet.* Computed from formula

$:+\left(\frac{3\,R}{2\,H}\right)^2 - \frac{3\,R}{2\,H} = T$. H *representing height of abutment to springing in feet.*

Height of Abutment to Springing.					Radius of Arch.	Height of Abutment to Springing.				
5	7.5	10	20	30		5	7.5	10	20	30
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
3.7	4.2	4.3	4.6	4.7	12	5.6	6.4	6.9	7.6	7.9
3.9	4.4	4.6	4.9	5	15	6	7	7.5	8.4	8.8
4.2	4.6	4.8	5.1	5.2	20	6.5	7.7	8.4	9.6	10
4.5	4.7	5.2	5.6	5.7	25	6.9	8.2	9.1	10.5	11.1
4.7	5.2	5.5	6	6.1	30	7.2	8.7	9.7	11.4	12
4.9	5.5	5.8	6.4	6.5	35	7.4	9.1	10.2	11.8	12.9
5.1	5.8	6.1	6.7	6.9	40	7.6	9.4	10.6	12.8	13.6
5.3	6	6.4	7.1	7.3	45	7.8	9.7	11	13.4	14.3
5.5	6.2	6.6	7.3	7.6	50	7.9	10	11.4	14	15

ɛ.—Abutments in Table are assumed to be without counterforts or wing-
A sufficient margin of safety must be allowed beyond dimensions here

verts for a road having double tracks are not necessarily twice the for a single track.

other and full notes, tables, etc., see Trautwine's Pocket Book, pp. 693–710.

MECHANICAL CENTRES.

:re are four Mechanical centres of force in bodies, namely, Centre avity, Centre of Gyration, Centre of Oscillation, and Centre of ssion.

Centre of Gravity.

TRE OF GRAVITY of a body, or any system of bodies rigidly con- l together, is point about which, if suspended, all parts will be in ɔrium.

ɔdy or system of bodies, suspended at a point *out* of centre of gravity, st with its centre of gravity vertical under point of suspension.

ɔdy or system of bodies, suspended at a point *out* of centre of gravity, ıccessively suspended at two or more such points, the vertical lines :h these points of suspension will intersect each other at centre of y of body or bodies.

tre of gravity of a body is not always within the bod

entres of gravity of two bodies, as B C, be connect of B and C from their common centre of gravity, *c*, *bodies.* Thus, B : C :: C *c* : *c* B.

o Ascertain Centre of Gravity of any Plane Figure M

end the figure by any point near its edge, and marl *ımb-line hung from* that point; then suspend it f. *d again mark direction* of plumb-line. Then centı. *ill be at point of* intersection of the two marks of plu.

Centre of gravity of parallel-sided objects may readily be found in this way. For instance, to ascertain centre of gravity of an arch of a bridge, draw elevation upon paper to a scale, cut out figure, and proceed with it as above directed, in order to find position of centre of gravity in elevation of the model. In actual arch, centre of gravity will have same relative position as in paper model.

In regular figures or solids, centre of gravity is same as their geometrical centres.

Line.

Circular Arc. $\frac{r\,c}{l}$ = *distance from centre, r representing radius, c chord, and l length of arc.*

Surfaces.

Square, Rectangle, Rhombus, Rhomboid, Gnomon, Cube, Regular Polygon, Circle, Sphere, Spheroid or Ellipsoid, Spheroidal Zone, Cylinder, Circular Ring, Cylindrical Ring, Link, Helix, Plain Spiral, Spindle, all Regular Figures, and Middle Frusta of all Spheroids, Spindles, etc.

The centre of gravity of the surfaces of these figures is *in their geometrical centre.*

Triangle.—On a line drawn from any angle to the middle of opposite side, at two thirds of the distance from angle.

Trapezium.—Draw two diagonals, and ascertain centres of gravity of each of four triangles thus formed; join each opposite pair of these centres, and *is at intersection of the lines.*

Trapezoid. $\left(\frac{B+2\,b}{B+b}\right)\times\frac{m}{3}$ = *distance from* B *on a line joining middle of the parallel sides* B *b, m representing middle line.*

Circular Arc. $\frac{c\,r}{l}$ = *distance from centre of circle.*

Sector of a Circle. $.4244\,r$ = *distance from centre of circle, c representing chord.*

Semicircle. $.4244\,r$ = *distance from centre.*

Semi-semicircle. $.4244\,r$ = *distance from both base and height and at their intersection.*

Segment of a Circle. $\frac{c^3}{12\,a}$ = *distance from centre, a representing area of segment.*

Sector of a Circular Ring. $\frac{4}{3}\times\frac{\sin.\,.5\angle}{\text{arc}\,\angle}\times\frac{r^3-r'^3}{r^2-r'^2}$ = *distance from centre of arcs, r and r′ representing the radii.*

ILLUSTRATION.—Radii of surfaces of a dome are 5 and 3.5 feet, and angle ($\angle$) at centre = 130°.

$$\frac{4}{3}\times\frac{\sin.\,65^\circ}{\text{arc }130^\circ}\times\frac{125-42.875}{25-12.25}=\frac{4}{3}\times\frac{.9063}{2.2689}\times\frac{82.125}{6.8067\times12.75}=3.43\textit{ feet.}$$

·here, Spherical Segment, and Spherical Zone, At centre of their

Zone.—Ascertain centres of gravity of trapezoid and segments zone; draw a line (equally dividing zone) perpendicular to ınect centres of segments by a line cutting perpendicular to

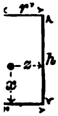
e of gravity of figure will be on perpendicular, toward i proportionate distance of difference between centres of gr and line connecting centres of segments, as area of se ı of trapezoid.

m and Wedge.—When end is a Parallelogram, *in their geometrical ;* when the end is a Triangle, Trapezium, etc., it is *in middle of its at same distance from base, as that of triangle or trapezoid of which section.*

abola in its axis = *.6 distance from vertex.*

moid.—At same distance from its base as that of the trapezoid or ium, which is a section of it.

e.—On a line connecting centres of gravity of arcs at a proportionate point to respective areas of arcs.



Co-ordinates. $\left(r + r' - \frac{r\,r'}{r + r'}\right)\frac{1}{3} = z,$

and $\left(\frac{2\,r' + r}{r + r'}\right)\frac{h}{3} = x.$

Solids.

, Parallelopipedon, Hexahedron, Octahedron, Dodecahedron, Icosahe- Cylinder, Sphere, Right Spherical Zone, Spheroid or Ellipsoid, Cylin- Ring, Link, Spindle, all Regular Bodies, and Middle Frusta of all ids and Spindles, etc. Centre of gravity of these figures *is in their rical centre.*

hedron.—In common centre of centres of gravity of the triangles made by a through centre of each side of the figures.

and Pyramid. .25 *of line joining vertex and centre of gravity of base* = *dis- rom base.*

tum of a Cone or Pyramid. $\frac{(r + r')^2 + 2\,r^2}{(r + r')^2 - r\,r'} \times \frac{1}{4}\,h$ = *distance from centre r end, r and r', in a cone representing radii, and in a pyramid sides, and h*

, Frustum of a Cone, Pyramid. Frustum of a Pyramid, and Ungula.— ie distance from base as in that of triangle, parallelogram, or semicir- ich is a right section of them.

isphere. $.375\,r$ = *distance from centre.*

rical Segment. $3.1416\,vs^2\left(r - \frac{vs}{2}\right)^2 \div v$ = *distance from centre, vs repre- versed sine, and v volume of segment.* $\left(\frac{8\,r - 3\,h}{12\,r - 4\,h}\right) \times h$ = *distance from*

rical Sector. $.75\,(r - .5\,h)$ = *distance from centre.* $\frac{2\,r + 3\,h}{8}$ = *distance ertex.*

als.—Plane, *in its geometrical centre.* Conical, *at a distance from the 25 of line joining vertex and centre of gravity of base.*

tum of a Circular Spindle. $\frac{r^2 - r'^2}{2\,(h - D.z)}$ = *distance from centre of spindle, senting distance between two bases,* D *distance of centre of spindle from centre e, and z generating arc, expressed in units of radius.*

ent of a Circular Spindle. $\frac{r^2}{2\,(h - D.z)}$ = *distance from centre of spindle.*

-spheroids.—Prolate. $.375\,a$.—*Oblate.* $.375\,a$ = *distance fr*

-spheroid or Ellipsoid and its Segment.—See Haswell's M 1 282.

z of Spheroids or Ellipsoids. Prolate. $.75\,\frac{h\,(2\,a^2 - h^2}{3\,a^2 - h^2}$

spheroid, a representing semi-transverse diameter in a pr *igate in an oblate frustum.*

Centre of gravity of
way. For instance, to
draw elevation upon pa
above directed, in order
the model. In actual ar
as in paper model.

In regular figures or
centres.

Circular Arc. $\frac{r\,c}{l}=$ *di*
length of arc.

Square, Rectangle, Rh
Circle, Sphere, Spheroid
Ring, Cylindrical Ring, I
ures, and Middle Frusta

The centre of gravity o
cal centre.

Triangle.—On a line dr
at two thirds of the distan

Trapezium.—Draw two
of four triangles thus form
is at intersection of the lin

Trapezoid. $\left(\frac{B+2\,b}{B+b}\right)\times$
parallel sides B *b, m represen*

Circular Arc. $\frac{c\,r}{l}=$ *distan*

Sector of a Circle. $.4244\,r=$

Semicircle. $.4244\,r=$ *distan*

Semi-semicircle. $.4244\,r=$ *d*
section.

Segment of a Circle. $\frac{c^3}{12\,a}=$

Sector of a Circular Ring.

arcs, r and r′ representing the ra

ILLUSTRATION.—Radii of surf
centre $= 130^\circ$.

$$\frac{4}{3}\times\frac{\sin.\,65^\circ}{\text{arc }130^\circ}\times\frac{125-42}{25-12}$$

Hemisphere, Spherical Seg
heights.

Circular Zone.—Ascertain c
comprising zone; draw a lin
chords; connect centres of se
chords.

Then centre of gravity of fi
chord, at such proportionate di
of trapezoid and line connectin
bears to area of trapezoid.

Centre of Gyration.

Centre of Gyration is that point in any revolving body or system bodies in which, if the whole quantity of matter were collected, the *angular velocity* would be the same; that is, the *Momentum* of the body system of bodies is centred at this point, and the position of it is a ean proportional between the centres of Oscillation and Gravity.

If a straight bar of uniform dimensions was struck at this point, the -oke would communicate the same *angular velocity* to the bar as if the hole bar was collected at that point.

The *Angular velocity* of a body or system of bodies is the motion of a line nnecting any point and the centre or axis of motion: it is the same in all rts of the same revolving body.

In different unconnected bodies, each oscillating about a common centre, eir *angular velocity* is as the velocity directly, and as the distance from e centre inversely. Hence, if their velocities are as their radii, or distances om the axis of motion, their angular velocities will be equal.

When a body revolves on an axis, and a force is impressed upon it suffi-nt to cause it to revolve on another, it will revolve on neither, but on a e in the plane of the axes, dividing the angle which they contain; so that sine of each part will be in the inverse ratio of the angular velocities th which the bodies would have revolved about these axes separately.

Weight of revolving body, multiplied into height due to the velocity with ich centre of gyration moves in its circle, is energy of body, or mechani- power, which must be communicated to it to give it that motion.

Distance of centre of gyration from axis of motion is termed the *Radius gyration;* and the moment of inertia is equal to product of square of lius of gyration and mass or weight of body.

The moment of inertia of a revolving body is ascertained exactly by as-taining the moments of inertia of every particle separately, and adding em together; or, approximately, by adding together the moments of the all parts arrived at by a subdivision of the body.

o Compute Moment of Inertia of a Revolving Body.

Rule.—Divide body into small parts of regular figure. Multiply mass weight of each part by square of distance of its centre of gravity from is of revolution. The sum of products is moment of inertia of body.

Note.—The value of moment of inertia obtained by this process will be more act, the smaller and more numerous the parts into which body is divided.

o Compute Radius of Gyration of a Revolving Body about its Axis of Revolution.

Rule.—Divide moment of inertia of body by its mass, or its weight, and uare root of quotient is length of radius of gyration.

Note.—When the parts into which body is divided are equal, radius of gyration ay be determined by taking mean of all squares of distances of parts from axis revolution, and taking square root of their sum.

Or, $\sqrt{R^2 + r^2 \div 2} = G$. R *and* r *representing radii.*

Example.—A straight rod of uniform diameter and 4 feet in length, weighs 4 lbs.; at is its inertia, and where is its radius or centre of gyration?

Each foot of length weighs 1 lb., and if divided into 4 parts, centre of gyration ch is *respectively* .5, 1.5, 2.5, and 3.5 feet. Hence,

$$\left.\begin{array}{l} 1 \times .5^2 = .25 \\ 1 \times 1.5^2 = 2.25 \\ 1 \times 2.5^2 = 6.25 \\ 1 \times 3.5^2 = 12.25 \end{array}\right\} 21 = \textit{inertia}, \text{ which} \div 4 = 5.25, \text{ and } \sqrt{5} \text{ feet radius.}$$

Following are distances of centres of gyration from centre of m various revolving bodies:

Straight, uniform Rod or *Cylinder* or *thin Rectangular Plate* revolving a end; *length* × .5773, and revolving about their centre; *length* × .2886.

The general expression is, when revolving at any point of its length,

$$\sqrt{\left(\frac{l^3+l'^3}{3(l+l')}\right)}.$$ *l and l' representing length of the two arms.*

Circular Plane, revolving on its centre; *radius of circle* × .7071; *Circle a Wheel or Disc of uniform Thickness*, revolving about one of its diamete axis; *radius* × .5.

Solid Cylinder, revolving about its axis; *radius* × .7071.

Solid Sphere, revolving about its diameter as an axis; *radius* × .6325.

Thin, hollow Sphere, revolving about one of its diameters as an axis × .8164. *Surface of sphere* .8615 *r*.

Sphere and Solid Cylinder (vertical), at a distance from axis of revo $\sqrt{l^2+.4\,r^2}$ *for sphere*, and $\sqrt{l^2+.5\,r^2}$ *for cylinder, l representing length o tion to centre of sphere and cylinder.*

Cone, revolving about its axis; *radius of base* × .5447; revolving about tex $=\sqrt{12\,h^2+3\,r^2\div 20}$, *h representing height, and r radius of base;* r about its base $=\sqrt{2\,h^2+3\,r^2\div 20}$.

Circular Ring, as *Rim of a Fly-wheel or Hollow Cylinder*, revolving a diameter $=\sqrt{R^2+r^2}\div 2$, R *representing radius of periphery, and r of in of ring.*

Fly-wheel $=\sqrt{\dfrac{6\,W\,(R^2+r^2)+w\,(4\,r^2+l^2)}{12\,(W+w)}}$, W *and w representing w rim and of arms and hub, and l length of arms from axis of wheel.*

Section of Rim. $\sqrt{\dfrac{4\,d^2+c^2}{12}+r^2+r\,d}$. *d representing depth and c p of rim.*

Parallelopiped, revolving about one end, distance from end $=\sqrt{\dfrac{4\,l^2+b}{12}}$ *resenting breadth.*

ILLUSTRATION.—In a solid sphere revolving about its diameter, diamet 2 feet, distance of centre of gyration is $12\times .6325=7.59$ *ins.*

To Compute Elements of Gyration.

$\dfrac{G\,W\,v}{r\,t\,g}=P$; $\dfrac{P\,r\,t\,g}{W\,v}=G$; $\dfrac{G\,W\,v}{P\,t\,g}=r$; $\dfrac{P\,r\,t\,g}{G\,v}=W$; $\dfrac{G}{P}$

$\dfrac{P\,r\,t\,g}{G\,W}=v$. G *representing distance of centre of gyration from axis of W weight of body, t time power acts in seconds, v velocity in feet per second by revolving body in that time, and r distance of point of application of po axis of body, as length of crank, etc.*

ILLUSTRATION 1.—What is distance of centre of gyration in a fly-whee 224 lbs., length of crank 7 feet, time of rotation 10 seconds, weight of wh lbs., and velocity of it 8 feet per second?

$$\frac{7\times 10\times 32.166}{5600\times 8}=\frac{504\,373}{42\,800}=11.78\ \textit{feet.}$$

ght of a fly-wheel making 12 revolutions per mi lled at 2 feet from its axis 84 lbs., time of rota e of gyration of wheel 3.5 feet?

eet = velocity. Then $\dfrac{84\times 2\times 6\times 32.166}{3.5\times 5.0265}$

e *Body is a Compound one.* RULE.—Multiply weight of several · bodies by squares of their distances in feet from centre of mo-ιtion, and divide sum of their products by weight of entire mass; root of quotient will give distance of centre of gyration from ιotion or rotation.

—If two weights, of 3 and 4 lbs. respectively, be laid upon a lever (which med to be without weight) at the respective distances of 1 and 2 feet, ınce of centre of gyration from centre of motion (the fulcrum)?

$$=3; \quad 4 \times 2^2 = 16; \quad \frac{3+16}{3+4} = \frac{19}{7} = 2.71, \text{ and } \sqrt{2.71} = 1.64 \textit{ feet.}$$

ıgle weight of 7 lbs., placed at 1.64 feet from centre of motion, and re-ꞩame time, would have same *momentum* as the two weights in their laces.

ntre of Gravity is given. RULE.—Multiply distance of centre of from centre or point of suspension, by distance of centre of grav-ıme point, and square root of product will give distance of centre l.

—Centre of oscillation of a body is 9 feet, and that of its gravity 4 feet of rotation or point of suspension; at what distance from this point is ration?

$$9 \times 4 = 36, \text{ and } \sqrt{36} = 6 \textit{ feet.}$$

mpute Centre of Gyration of a Water-wheel.

Multiply severally twice weight of rim, as composed of buckets, etc., and twice that of arms and that of water in the buckets el is in operation) by square of radius of wheel in feet; divide ice sum of these several weights, and square root of quotient will ıce in feet.

—In a wheel 20 feet in diameter, weight of rim is 3 tons, weight of ꞩ, and weight of water in buckets 1 ton; what is distance of centre of ım centre of wheel?

$$\begin{aligned} &= 3 \text{ tons} \times 10^2 \times 2 = 600 \\ &= 2 \text{ tons} \times 10^2 \times 2 = 400 \\ &= 1 \text{ ton} \times 10^2 = \underline{100} \\ &\phantom{= 1 \text{ ton} \times 10^2 \times 2 =\ } 1100 \end{aligned} \qquad 3+2+1 \times 2 = 12 \textit{ sum of weights.} \qquad \text{Hence } \sqrt{\frac{1100}{12}} = \sqrt{91.67} = 9.57 \textit{ feet.}$$

FORMULAS.—P *representing power*, H *horses' power*, F *force applied to in lbs.*, M *mass of revolving body in lbs.*, r *radius upon which* F *acts in ınce from axis of motion to centre of gyration in feet*, t *time force is ap-onds*, n *number of revolutions in time* t, x *angular velocity, or number of per minute at end of time* t, *and* $G = \frac{32.166\, F\, r^2}{M\, d^2}$.

$$=t; \quad \frac{2\, p\, r^2\, x}{60\, G} = t; \quad \frac{M\, x\, d^2}{153.5\, t\, r} = F; \quad \frac{M\, n\, d^2}{2.56\, t^2\, F} = r; \quad \frac{2.56\, t^2\, F\, r}{M\, d^2} = n;$$

$$\frac{t\, F\, r}{l^2} = x; \quad \frac{244\, t\, P}{x^2\, d^2} = M; \quad \frac{x^2\, M\, d^2}{244\, t} = P; \quad \frac{x^2\, M\, d^2}{134\,100\, t} = H.$$

TION.—Rim of a fly-wheel weighing 7000 lbs. ... nd 5.75 is its centre of gyration, and what force mu ... feet f motion to give it an angular velocity of 130 r ... in ? how many revolutions will it make in 40 s ... its

$$\frac{130^2 \times 7000 \times 6.14^2}{134\,100 \times 40} = \frac{4\,459\,862\,680}{5\,364\,000} = 829.7 \text{ l}$$

$$\textit{gyration} = \sqrt{\frac{6.5^2 + 5.75^2}{2}} = 6.14 \textit{ feet.} \quad \text{Then F} =$$

$$793.7 \textit{ lbs.}, \text{ and } \frac{2.56 \times 40^2 \times 2793.7 \times 2}{7000 \times 6.14^2} = 86.67 \text{ revs.}$$

$\frac{l\, l^2}{3} \div W \times g =$ *distance from axis.* Or, square radius of gyration of body ·ide by distance of centre of gravity from axis of suspension.

[PLE.—Where is centre of oscillation in a rod 9 feet in length from its point ension, and weighing 9 lbs.?

$\frac{9}{2} = 40.5 =$ *product of weight and its centre of gravity;* $\frac{9 \times 9^2}{3} = 243 =$ *quo-* *product of weight of body and square of its length* $\div 3$; $\frac{243}{40.5} = 6$ *feet.*

n Point of Suspension is not at End of Rod. RULE.—To cube of :e of point of suspension from top of rod or bar, add cube of its dis- from lower end, and multiply sum by 2.

ide product by three times difference of squares of these distances, and it is distance of point of oscillation from point of suspension.

[PLE.—A homogeneous rod of uniform dimensions, 6 feet in length, is sus- 1.5 feet from its upper end; what is distance of point of oscillation from suspension?

$$6 - 1.5 = 4.5. \quad \frac{2\,(4.5^3 + 1.5^3)}{3\,(4.5^2 - 1.5^2)} = \frac{189}{54} = 3.5 \textit{ feet.}$$

tres of Oscillation and Percussion in Bodies of Various Figures.

Axis of Motion is in Vertex of Figure, and when Oscillation or Motion is Facewise.

t Line, or any figure of uniform shape and density $= .66\, l$.
:les Triangle $= .75\, h$. *Circle* $= 1.25\, r$.
bola $= .714\, h$. *Cone* $= .8\, h$.
1 Axis of Motion is in Centre of Body. *Wheel* $= .75$ *radius.*

n Oscillation or Motion is Sidewise. Right Line, or any figure of uni- hape and density $= .66\, l$. *Rectangle*, suspended at one angle $= .66$ *of di-*

bola, if suspended by its vertex $= .714$ of axis $+ .33$ parameter; if suspended dle of its base $= .57$ of axis $+ .5$ parameter.

r of a Circle $= \frac{3 \text{ arc } r}{4\, c}$, *c representing chord of arc, and r radius of base.*

e $= .75\, d$. *Cone* $= \frac{4}{5}$ axis $+ \frac{r^2}{5 \text{ axis}}$.

re $= \frac{2\, r^2}{5\,(c + r)} + r + c$, *c representing length of cord by which it is suspended.*

Ascertain Centres of Oscillation and Percussion experimentally.

end body very freely from a fixed point, and make it vibrate in small arcs, number of vibrations it makes in a minute, and let number made in a min- represented by n; then will distance of centre of oscillation from point of sion be $= \frac{140\,850}{n^2} =$ *ins.*

length of a pendulum vibrating seconds, or 60 times in a mi *ins.*, and lengths of pendulums being reciprocally as the squares *tions made in same time*, therefore $n^2 : 60^2 :: 39.125 : \frac{60^2 \times 39.1}{n^2}$ *gth of pendulum which vibrates n times in a minute*, or dista *ion below axis of motion.*

To Compute Centres of Oscillation or Percussion of a System of Particles or Bodies.

RULE.—Multiply weight of each particle or body by square of its distance from point of suspension, and divide sum of their products by sum of weights multiplied by distance of centre of gravity from point of suspension, and quotient will give centre required, measured from point of suspension.

$$\text{Or, } \frac{W\,d^2 + W'\,d'^2}{W\,g + W'\,g'} = \textit{distance of centre.}$$

EXAMPLE 1.—Length of a suspended rod being 20 feet, and weight of a foot in length of it equal 100 oz., has a ball attached at under end weighing 100 oz.; at what point of rod from point of suspension is centre of percussion?

$100 \times 20 = 2000 =$ *weight of rod;* $2000 \times \frac{20}{2} = 20\,000 =$ *momentum of rod, or product of its weight, and distance of its centre of gravity;* $\frac{2000 \times 20^2}{3} = 266\,666.66 =$ *force of rod;* $1000 \times 20^2 = 400\,000 =$ *force of ball.*

Then $\frac{266\,666.66 + 400\,000}{20\,000 + 20\,000} = 16.66$ *feet.*

2.—Assume a rod 12 feet in length, and weighing 2 lbs. for each foot of its length, with 2 balls of 3 lbs. each—one fixed 6 feet from the point of suspension, and the other at the end of the rod; what is the distance between the points of suspension and percussion?

$12 \times 2 \times \frac{12}{2} = 144 =$ *momentum of rod.*
$3 \times 6 = 18 =$ " *of 1st ball.*
$3 \times 12 = 36 =$ " *of 2d ball.*
198 *sum of moments.*

$\frac{24 \times 12^2}{3} = \frac{3456}{3} = 1152 =$ *force of rod.*
$3 \times 6^2 = 3 \times 36 = 108 =$ " *of 1st ball.*
$3 \times 12^2 = 3 \times 144 = 432 =$ " *of 2d ball.*
1692 *sum of forces.*

Then $1692 \div 198 = 8.545$ *feet.*

MECHANICS.

MECHANICS is the science which treats of and investigates effects of forces, motion and resistance of material bodies, and of equilibrium; it is divided into two parts—STATICS and DYNAMICS.

STATICS treats of equilibrium of forces or bodies at rest. DYNAMICS of forces that produce motion, or bodies in motion.

These bodies are further divided into *Mechanics of Solid, Fluid,* and *Aeriform bodies;* hence the following combinations:

1. *Statics of Solid Bodies, or Geostatics.*
2. *Dynamics of Solid Bodies, or Geodynamics.*
3. *Statics of Fluids, or Hydrostatics.*
4. *Dynamics of Fluids, or Hydrodynamics.*
5. *Statics of Aeriform Bodies, or Aerostatics.*
6. *Dynamics of Aeriform Bodies, Pneumatics or Aerodynamics.*

Forces are various, and are divided into moving forces or resistances: ...

Gravity,	*Heat or Caloric,*	*Inertia,*
Muscular,	*Magnetism,*	*Cohesion,*
...sticity and Contractility,	*Percussion,*	*Adhesion,*
...al,	*Expansion,*	*and Explosion.*

Two forces of equal magnitude applied to or operating ... parallel and opposite directions, but not in same line of action ... *couple*, and its force is sum or magnitude of the two equal forces.

Quantity of motion in a moving body, which is always ... quantity of matter and its velocity.

...ties of two moving bodies are inversely as their quan... *momenta* are equal.

STATICS.

Composition and Resolution of Forces.

When two forces act upon a body in same or in an opposite direc-n, effect is same as if only one force acted upon it, being sum or ference of the forces. Hence, when a body is drawn or projected in ections immediately opposite, by two or more unequal forces, it is affected f it were drawn or projected by a single force equal to difference between two or more forces, and acting in direction of greater force.

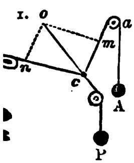
This single force, derived from the combined action of two or more forces, heir *Resultant*.

he process by which the *resultant* of two or more forces, or a single e equivalent in its effect to two or more forces, is determined, is termed *Composition of Forces*, and the inverse operation; or, when combined cts of two or more forces are equivalent to that of a single given force, process by which they are determined is termed the *Decomposition or olution of Forces.* Two or more forces which are equivalent to a single e are termed *Components.*

When two forces act on same point their intensities are represented by sides a parallelogram, and their combined effect will be equivalent to that of a le force acting on point in direction of diagonal of parallelogram, the nsity of which is proportional to diagonal.

ILLUSTRATION.—Attach three cords to a fixed point, *c*, Fig. 1; let *c a* and *c b* pass over fixed rollers, and suspend weights A and B therefrom.

1.



Point *c* will be drawn by the forces A and B in directions *a c* and *b c*. Now, in order to ascertain which single force, P, would produce the same effect upon it, set off the distances *c m* and *c n* on the cords in the same proportion of length as weights of A and B; that is, so that *c m* : *c n* :: A : B; then draw parallelogram *c m o n* and diagonal *o c*, and it will represent a single force, P, acting in its direction, and having same ratio to weights A or B as it has to sides *c m* or *c n* of parallelogram. Consequently, it will produce same effect on point *c* as combined actions of A and B.

A parallelogram, constructed from lateral forces, and diagonal of which is mean force, is termed a *Parallelogram of Forces.*

. 2.

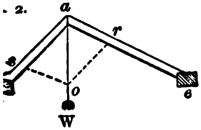


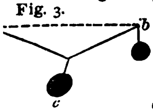
ILLUSTRATION.—Assume a weight, W, Fig. 2, to be suspended from *a*; then, if any distance, *a o*, is set off in numerical value upon the vertical line, *a* W, and the parallelogram, *o r a s*, is completed, *a s* and *a r*, measured upon the scale, *a o*, will represent strain upon *a c* and *a e* in same proportion that *a o* bears to weight W.

If several forces act upon same point, and their intensities taken in order represented by sides of a polygon, except one, a single force proportioned and acting in direction of that one side will be their resultant.

To Resolve a Single Force into a Pair of Forces.—Figs. 3 and 4.

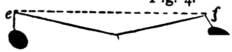
The ends of a cord, Fig. 3, are led over two points, *a* and *b*, and in centre of d at *c* a weight of 4 lbs. is suspended. If distances *a c*, *b c*, are each 1 foot, distance *a b* should be 18 ins.

Fig. 3.



When cord is in this position, weight at *c* draws upon *c a* and *c b* with a force of 3 lbs.; hence *c* of 4 lbs. is equal to two forces of 3 lbs. each in direction of *a c* and *b c*.

Fig. 4.



ply ends of cord to *e f*, Fig. 4, distance being 22 ins., then th ch 5 lbs.; hence one force of 4 lbs. is equal to two of 5 lbs.

Equilibrium of Forces.

Two bodies which act directly against each other in same line are in equilibrium when their quantities of motion are equal; that is, when product of mass of one, into velocity with which it moves or tends to move, is equal to product of mass of other, into its actual or virtual * velocity.

When the velocities with which bodies are moved are same, their forces are proportional to their masses or quantities of matter. Hence, when equal masses are in motion, their forces are proportional to their velocities.

Relative magnitudes and directions of any two forces may be represented by two right lines, which shall bear to each other the relations of the forces and which shall be inclined to each other in an angle equal to that made by direction of the forces.

Fig. 4.

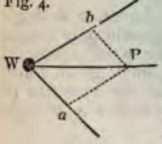


ILLUSTRATION.—Assume a body, W, to weigh 150 lbs., and resting upon a smooth surface, to be drawn by two forces a and *b*, Fig. 5. = 24 and 30 lbs., which make with each other an angle, *a* W *b* = 105°, in which direction and with what acceleration will motion occur?

$\angle\, a\,W\,b = 105°$, and cos. $180° - 105° = \cos. 75°$, makes *force.*

$$P = \sqrt{30^2 + 24^2 - 2 \times 30 \times 24 \cos. 75°} = \sqrt{900 + 576 - 1440 \cos. 75°}$$
$$= \sqrt{1476 - (1440 \times .25882)} = \sqrt{1103.3} = 33.21 \text{ lbs.}$$

The acceleration is $\frac{P\,g}{W} = \frac{33.21 \times 32.166}{150} = 7.1215$ *feet.*

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---

* Virtual velocity is the velocity which a body in equilibrium would acquire were the equilibrium to be disturbed.

† It is compared, because it is not referable to any standard, as a ton, pound, etc. Thus, a cannon-ball weighing 15 lbs., projected with a velocity of 1500 feet per second, ... body, its momentum, according to the above rule, would be 15 × 1500 = 22 500; ... is a pressure with which it cannot be compared.

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RMULAS. fv, $\frac{fs}{t}$, H 550, and $\frac{W}{t}=P$; $\frac{P}{v}$, $\frac{W}{s}$, and $\frac{H\,550}{v}=f$; $\frac{s}{t}$, $\frac{H\,550}{f}$, and $\frac{W}{ft}=v$; vt, $\frac{Pt}{f}$, $\frac{W}{f}$, and $\frac{H\,550\,t}{f}=s$; $\frac{sf}{P}$, $\frac{s}{v}$, $\frac{W}{fv}$, $\frac{fs}{H\,550}=t$; fs, H 550 t, P t, and $fvt=W$; $\frac{P}{550}$, $\frac{fv}{550}$, $\frac{fs}{550\,t}$, and $=H$. P *representing power in effect, body, or momentum, f force in lbs., v and city and space in feet per second, t time in seconds,* H *horse-power, and* W *work ot-lbs.*

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$$25 + \overline{5 \times 3} = 40 \textit{ feet.}$$

–A locomotive having an initial velocity of 30 feet per second is so retarded n each second it loses 4 feet; what is its velocity after 6 seconds?

$$30 - \overline{4 \times 6} = 6 \textit{ feet.}$$

Uniform Motion Accelerated.

In this motion, velocity acquired at end of any time whatever is equal to product of accelerating force into time, and space described is equal to product of half accelerating force into square of time, or half product of velocity and time of acquiring the velocity.

Spaces described in successive seconds of time are as the odd numbers, 1, 3, 5, 7, 9, etc.

Gravity is a constant force, and its effect upon a body falling freely in a vertical line is represented by g, and the motion of such body is uniformly accelerated.

The following theorems are applicable to all cases of motion uniformly accelerated by any constant force, F:

$$.5\,t\,v = .5\,g\,F\,t^2 = \frac{v^2}{2\,g\,F} = s. \qquad \frac{2\,s}{v} = \frac{v}{g\,F} = \sqrt{\frac{s}{.5\,g\,F}} = t.$$

$$\frac{2\,s}{t} = g\,F\,t = \sqrt{2\,g\,F\,s} = v. \qquad \frac{v}{g\,t} = \frac{2\,s}{g\,t^2} = \frac{v^2}{2\,g\,s} = F.$$

When gravity acts alone, as when a body falls in a vertical line, F *is omitted. Thus,*

$$.5\,g\,t^2 = \frac{v^2}{2\,g} = s. \qquad g\,t = \sqrt{2\,g\,s} = v. \qquad \frac{v}{g} = \sqrt{\frac{2\,s}{g}} = t. \qquad \frac{v}{t} = \frac{2\,s}{t^2} = \frac{v^2}{2\,s} = g.$$

t representing time in seconds, and s velocity in feet per second.

If, instead of a heavy body falling freely, it be projected vertically upward or downward with a given velocity, v, then $s = t\,v \mp .5\,g\,t^2$; an expression in which $-$ must be taken when the projection is upward, and $+$ when it is downward.

ILLUSTRATION 1.—If a body in 10 seconds has acquired a velocity by uniformly accelerated motion of 26 feet, what is accelerating force, and what space described in that time?

$26 \div 10 = 2.6 =$ *accelerating force;* $\frac{2.6}{2} \times 10^2 = 130$ *feet = space described.*

2.—A body moving with an acceleration of 15.625 feet describes in 1.5 seconds a space $= \frac{15.625 \times (1.5)^2}{2} = 17.578$ *feet.*

3.—A body propelled with an initial velocity of 3 feet, and with an acceleration of 5 feet, describes in 7 seconds a space $= 3 \times 7 + 5 \times \frac{7^2}{2} = 143.5$ *feet.*

4.—A body which in 180 seconds changes its velocity from 2.5 to 7.5 feet, traverses in that time a distance of $\frac{2.5 + 7.5}{2} \times 180 = 900$ *feet.*

5.—A body which rolls up an inclined plane with an initial velocity of 40 feet per second, by which it suffers a retardation of 8 feet, ascends only $\frac{40}{8} = 5$ *seconds,* and $40^2 \div \overline{2 \times 8} = 100$ *feet* in height, then rolls back, and returns, after 10 seconds, with a velocity of 40 feet, to its initial point; and after 12 seconds arrives at a distance of $40 \times 12 - \overline{4 \times 12^2} = 96$ *feet below point, assuming plane to be extended backward.*

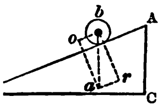
Circular Motion.

$$\frac{2\,p\,r\,n}{60} = \frac{2\,p\,r\,n'}{t} = v; \qquad \frac{5500\,\text{HP}}{r\,n} = \frac{W}{2\,p\,r\,n'} = f; \qquad \frac{f\,r\,n}{5500} = \frac{f\,2\,p\,r\,n}{550 \times 60} = \text{HP}$$

$f\,2\,p\,r\,n' = \frac{f\,t\,2\,p\,r\,n}{60} = W.$ r representing radius in feet, n number of revolutions *of circle per minute,* n' total revolutions, f force in lbs., t time in seconds, and HP *horse-power.*

Motion on an Inclined Plane.

To Ascertain Conditions of Motion by Gravity.



Assume A B, Fig. 6, an inclined plane, B C its base, A C its height, and b a body descending the plane; from dot, centre of gravity of body, draw $b\,a$ perpendicular to B C, representing pressure of b by gravity; draw $b\,o$ parallel and $b\,r$ perpendicular to A B, and complete parallelogram; then force $b\,a$ is equal to both $b\,o$, $b\,r$, of which $b\,r$ is sustained by reaction of plane, and ›o is wholly effective in accelerating motion of body.

'his force be represented by f, and b a, by g or force of gravity, then by similar e, $f : g :: b\,o : b\,a : \text{A C} : \text{A B}$. Hence, $\frac{\text{A C} \times g}{\text{A B}} = f$.

$\text{A B} = l$, $\text{A C} = h$ and $\angle \text{A B C} = a$, then force which produces motion on the ›n f becomes $g\,\frac{h}{l}$, and g sin. a.

'efore, accelerating force on an inclined plane is constant, and equations of ı will be obtained by substituting its value of f for g in equations 1, 2, and › 618.

$$\frac{g\,h\,t^2}{2\,l},\quad \frac{l\,v^2}{2\,g\,h},\quad .5\,t\,v,\quad .5\,g\,t^2 \text{ sin. } a,\quad \text{and}\quad \frac{v^2}{2\,g \text{ sin. } a} = s.$$

$$\frac{2\,s}{t},\quad \frac{g\,h\,t}{l},\quad \sqrt{\frac{2\,g\,h\,s}{l}},\quad g\,t \text{ sin. } a,\quad \text{and}\quad \sqrt{2\,g\,s \text{ sin. } a} = v.$$

$$\frac{l\,v}{g\,h},\quad \sqrt{\frac{2\,l\,s}{g\,h}},\quad \frac{v}{g \text{ sin. } a},\quad \text{and}\quad \sqrt{\frac{2\,s}{g \text{ sin. } a}} = t.\quad a \textit{ representing } \angle \text{ A B C.}$$

en a Body is projected down or up an Inclined Plane, with a given Ve-— The distance which it will be from point of projection in a given rill be

$$t\,v \pm \frac{g\,h\,t^2}{2\,l},\ \text{and}\ \frac{t}{2\,l}(2\,l\,v \pm g\,h\,t) = s.$$

STRATION I.—Length of an inclined plane is 100 feet, and its angle of inclina- °; what is time of a body rolling down it, and velocity acquired?

$$\text{sin. } 60° = .866.$$

$$\sqrt{\frac{2 \times 100}{32.16 \times .866}} = \sqrt{7.18} = 2.68 \textit{ seconds}, \text{ and } 32.16 \times 2.68 \times .866 = 74.64 \textit{ feet.}$$

'f a body is projected up an inclined plane, which rises 1 in 6, with a velocity ›et per second, what will be its place and velocity at end of 6 seconds?

$$50 - \frac{32.16 \times 1 \times 6^2}{2 \times 6} = 203.52 \textit{ feet from bottom}, \text{ and } 50 - \left(32.16 \times 6 \times \frac{1}{6}\right) =$$
$$\text{2.16} = 17.84 \textit{ feet.}$$

ffect an ascent up an inclined plane in least time, its length, to its height, ›e as twice weight to power.

Work Accumulated in Moving Bodies.

.ntity of work stored in a body in motion is same as that which would umulated in it by gravity if it fell from the height due to the velocity. ıulated work expressed in foot-lbs. is equal to product of height so in feet, and weight of body in lbs. Height due to velocity is equal ıare of velocity divided by 64.4, and work and velocity may be de- directly from each other by following rules:

To Compute Accumulated Work.

.E.—Multiply weight in lbs. by square of velocity in feet per second, ›vide by 64.4, and quotient is accumulated work in foot-lbs.

$V = \frac{v^2 \times w}{64.4}$, *or,* $= w \times h$. *W representing work, w weight in lbs., and due to velocity in feet per second.*

Work by Percussive Force.

If a wedge is driven by strokes of a hammer or other heavy mass of percussive force is measured by quantity of work accumulated in st body. This work is computed by preceding rules, from weight of and velocity with which a stroke is delivered, or directly from hei fall, if gravity be percussive power.

Useful work done through a wedge is equal to work expended u assuming that there is no elastic or vibrating reaction from the strok the work had been exerted by a constant pressure equal to weight of ing body, exerted through a space equal to height of fall, or height its final velocity.

If elastic action intervenes, a portion of work exerted is absorbe elastic stress to resisting body; and the elastic action may be, in some so great as to absorb the work expended.

The principle of action of a blow on a wedge is alike applicable to of the stroke of a monkey of a pile-driver upon a pile.

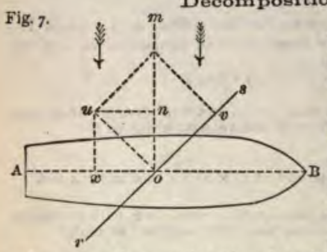
If there be no elastic action, the work expended being product of of monkey by height of its fall, is equal to work performed in driv pile: that is, to product of resistance to its descent by depth through it is driven by each blow of monkey.

Illustration.—If a horse draws 200 lbs. out of a mine, at a speed of 2 m hour, how many units of work does he perform in a minute, coefficient of frict

$\frac{2 \times 5280}{60} = 176$ *feet per minute.* Hence, $176 \times 200 + \overline{.05 \times 200} = 35\,210$

Decomposition of Force.

Fig. 7.



By parallelogram of force lustrated how a vessel is ena be sailed with a free wind and one.

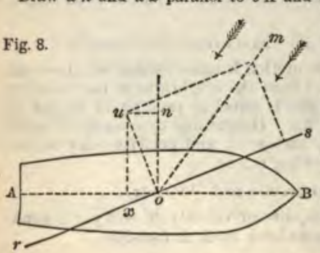
Assume wind to be free or in d of arrows, Fig. 7, and perpendi line A B, the course of vessel.

Let line $m\,o$ represent direct force of wind, and $r\,s$ plane of sa o draw $o\,u$ perpendicular to from m perpendicular, $m\,v$ on $m\,u$ on $o\,u$.

By principle of parallelogram force $m\,o$ may be decomposed and $o\,u$, since they are the sides of parallelogram of which $m\,o$, representi of wind, is diagonal. Force of wind, therefore, is measured by $o\,u$, both in tude and direction, and represents actual pressure on sail.

Draw $u\,n$ and $u\,x$ parallel to o A and $o\,m$, thus forming parallelogram Hence force $o\,u$ is equal to the and $o\,x$. Force $o\,n$ acts in a d perpendicular to vessel's course of $o\,x$ is to drive vessel onward.

Fig. 8.



It can thus be shown that w rection of sail bisects angle m effect of $o\,x$ is greater than whe in any other position.

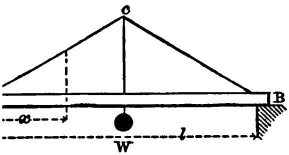
Assume wind to be ahead as tion of arrows, Fig. 8. Let $o\,m$ sent direction and force of wind, direction of sail; from o draw proceed as before, and $o\,u$ repres effective force that acts upon $o\,n$ that which drives her to leewa $o\,x$ that which drives her on her

For full treatises on this subject, see John C. Trautwine's Engineer's Pocket-book, Ex perimental Mechanics, London, 1871; and Dynamics, Construction of Machinery, etc., Warr, London, 1851.

MOMENTS OF STRESS.

Describe and Compute Moments of Stress on Girders or Beams.

Supported at Both Ends.



Loaded in Centre, Fig. 1. — Assume A B, a beam. At centre erect W c = $\frac{W\,l}{4}$. Connect A c and c B, and any vertical distance between them and A B will give moment required at that point.

$\frac{W\,x}{2}$ = M at any point. W *represent-* *eight or load, l length of span, x horizontal distance from nearest support at* M, *the moment of stress, is required.*

ISTRATION.—Assume $l = 10$ feet, W = 10 lbs., and $x = 3$ feet.

n, W $c = \frac{10 \times 10}{4} = 25$ *lbs. at centre of span;* and $\frac{10 \times 3}{2} = 15$ *lbs. at x.*

Loaded at Any Point, Fig. 2.— Proceed as for previous figure.

$\frac{W\,a\,b}{l}$ or W c = *maximum load.*

$\frac{W\,x\,b}{l}$ = M *between* A *and* W.

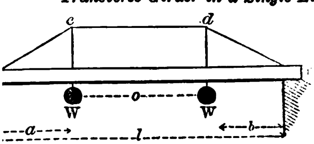
presenting least distance of W *to support,* *greatest distance.* $\frac{W\,x\,a}{l}$ = M *between* W *and* B.

ISTRATION.—Take elements as before with $a = 3$ feet, x 1.5, and x' 3.5 feet.

n, W $c = \frac{10 \times 3 \times 7}{10} = 21$ *lbs. at point of stress;* $\frac{10 \times 1.5 \times 7}{10} = 10.5$ *lbs. at x* *n* A *and* W, *and* $\frac{10 \times 3.5 \times 3}{10} = 10.5$ *lbs. at x between* W *and* B.

E.—x and x' must be taken from the pier, which is on the same side of W as f the stress desired.

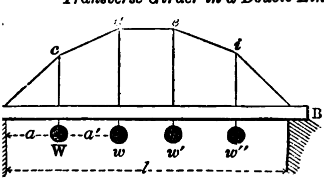
d with Two Equal Weights at Equal Distances from Supports, alike to a Transverse Girder in a Single Line of Railway.—Fig. 3.



At point of stress of weights erect W c and W d, each = W a. Connect A c d and B, and vertical distances between them and A B will give moments required.

$\frac{W\,(l - o)}{2} = W\,a = W\,b = M$ *at any point between weights.*

d with Four Equal Weights, symmetrically bearing from Centre, alike to a Transverse Girder in a Double Line of Railway.—Fig. 4.



At W and w'' erect W c, and $w''\,i = 2\,W\,a$, and at w and w' erect $w\,d$, $w'\,e$, each = W $(2\,a + a')$.

Connect A c d e i and B, and ordinates from them to A B will give moments required.

W $(2\,a + a')$ = M at w and w'; 2 W a = M at W and w''.

ILLUSTRATION.—Assume W each 10 lbs. 2 feet apart, and l 10 feet.

l, $10\,(2 \times 2 + 2) = 60$ at w or w', and $2 \times 10 \times 2 = 40$ at W or w''.

Equilibrium of Forces.

Two bodies which act directly against each other in same line are in equilibrium when their quantities of motion are equal: that is, when product mass of one, into velocity with which it moves or tends to move, is equal product of mass of other, into its actual or virtual * velocity.

When the velocities with which bodies are moved are same, their forces are proportional to their masses or quantities of matter. Hence, when equal masses are in motion, their forces are proportional to their velocities.

Relative magnitudes and directions of any two forces may be represented by two right lines, which shall bear to each other the relations of the forces and which shall be inclined to each other in an angle equal to that made by direction of the forces.

Fig. 4.

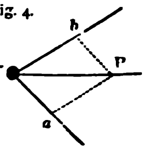


ILLUSTRATION.—Assume a body, W, to weigh 150 lbs., resting upon a smooth surface, to be drawn by two forces a and b, Fig. 5, = 24 and 30 lbs., which make with each other an angle, $a\,W\,b = 105°$, in which direction and with what acceleration will motion occur?

$\angle\, a\,W\,b = 105°$, and $\cos. 180° - 105° = \cos. 75°$, and force.

$$P = \sqrt{30^2 + 24^2 - 2 \times 30 \times 24 \cos. 75°} = \sqrt{900 + 576 - 1440 \cos. 75°}$$
$$= \sqrt{1476 - (1440 \times .25882)} = \sqrt{1103.3} = 33.21 \text{ lbs.}$$

The acceleration is $\frac{P\,g}{W} = \frac{33.21 \times 32.166}{150} = 7.1215$ *feet.*

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r more bodies, etc., are compared, two or more corresponding letters, , V, *v*, *v'*, *etc., are employed.*

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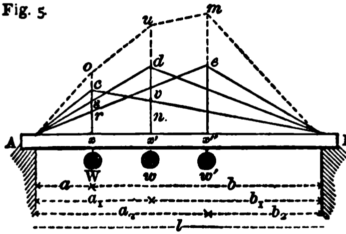


Loaded at Different Points.—Fig

Locate three weights, W, w, and w', as at $a\,b$, $a_1\,b_1$, $a_2\,b_2$.

Draw A c B, A d B, and A e B, three separate cases, by formula, $\frac{W\,a\,b}{l}$, Fig. 2.

Produce W c until W o = W r, and W c; W d until $w\,u = w\,n$, and $w\,d$, and $w'\,e$ to $w'\,m$ in like manner.

Connect A $o\,u\,m$ and B, and an ordinate therefrom, to A B will give moment of stress at the point taken.

ILLUSTRATION.—Take $a = 2$ feet, $a_1 = 4$, $a_2 = 6$, $b = 8$, $b_1 = 6$, $b_2 = 4$, W, w, and w' each 10 lbs., and $l = 10$ feet, carefully observing Note to Fig. 2.

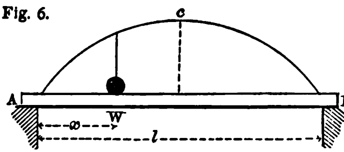
Then $\frac{1}{l}(W\,b\,x + w\,b_1\,x + w'\,b_2\,x) = M$ at x.

Take $x = 2$. Then $\frac{1}{10}(10 \times 8 \times 2 + \overline{10 \times 6 \times 2} + \overline{10 \times 4 \times 2}) = \frac{360}{10} = 36$ *lbs.*

$x' = 4$. $\frac{1}{10}(10 \times 2 \times 6 + \overline{10 \times 6 \times 4} + \overline{10 \times 4 \times 4}) = \frac{520}{10} = 52$ *lbs.*

$x'' = 6$. $\frac{1}{10}(10 \times 2 \times 4 + \overline{10 \times 4 \times 4} + \overline{10 \times 4 \times 6}) = \frac{480}{10} = 48$ *lbs.*

Fig. 6.



Loaded with a Rolling Weight.—Fig. 6.

Define parabola A c B as determined by $\frac{W\,l}{4}$ = the ordinate at c, and vertical distances between A B will give moments.

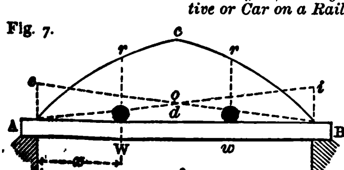
$$\frac{W\,x\,(l - x)}{l} = M \textit{ at any point}$$

Loaded Uniformly its Entire Length.—Define parabola as at Fig. 6, ordinate of which at $c = \frac{w\,l^2}{8}$. L *representing stationary or dead load per unit of length.*

$$\frac{L\,x}{2}\,(l - x) = M \textit{ at any point, and } \frac{w\,l^2}{8} = M \textit{ at centre.}$$

Loaded with Two Connected Weights, moving in either Direction, alike to a Locomotive or Car on a Railway.—Fig. 7.

Fig. 7.



Define parabola A c B as determined by $\frac{(W + w)\,l}{4} = c$.

At A and B erect A e, B i = w, connect A i and B e, and vertical distances between A o B and A c B will give moments.

$$\frac{x}{l}\left[(W + w)\ (l - x) - \overline{w\,d}\right] = \text{M}$$

eatest moment, when $x = \frac{l}{2} \pm \frac{w\,d}{2(W + w)}$. Or if W and w ...

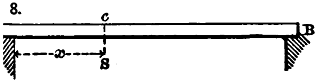
... $x = 3$, $d = 4$, and W w each 10 lbs., and l 10 feet.

... $\overline{\text{-0} \times 4}) = M$ at any point, as at W r, $w\,r$.

Shearing Stress.

Determine Shearing Stress at any Part of a Girder or Beam and under any Distribution of Load.

8.



Required to determine stress of a beam at any point as c, Fig. 8.

Assume $W =$ load between A and c, and w that between B and c.

Then $S x$ at $c = P - W$, or $P' - w$.

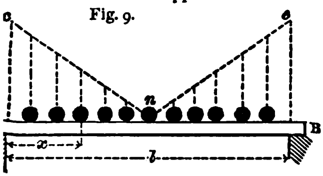
he greater of the two values to be taken.

x representing shearing stress at any point x, P *and* P′ *the reaction on supports to total load on beam between supports,* W *and w loads or stress concentrated at point.*

[T]o Describe and Ascertain Shearing Stress in a Girder or Beam.

Supported or Fixed at Both Ends.

Fig. 9.



Loaded Uniformly. Fig. 9.

At A and B, erect A c, B e, each equal to $\frac{W\,l}{2}$. Connect c and e at middle of span as at n, and vertical distances between A B and $c\,n\,e$ will give shearing stresses as determined by the ordinates to $c\,n\,e$.

$L\left(\frac{l}{2} - x\right) = S$. Sign of result to isregarded. L *representing distributed load per unit of length.*

[IL]LUSTRATION.—Assume $L = 10$ lbs. per foot, $l = 10$, and $x = 2.5$ feet.

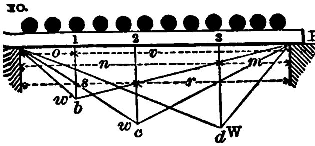
$$\text{Then } 10\left(\frac{10}{2} - 2.5\right) = 25 \textit{ lbs.}$$

[NO]TE.—The moment of rupture at any point, produced by several loads acting [simu]ltaneously on a beam, is equal to the sum of the moments produced by the [seve]ral loads acting separately.

[Fo]r other Formulas and Diagrams see Strains in Girders, by William Humber, C.E., London, 1872.

[Illust]ration deduced by Graphic Delineation of Greatest Stress, with a Uniformly Distributed Load of 14 000 *Lbs.*—Fig. 10.

10.



Determine moment of weights by formulas $\frac{W\,m\,n}{l}$, $\frac{w\,r\,s}{l}$, and $\frac{w'\,o\,v}{l}$.

Assume $W = 7000$ lbs., $w = 4000$, and $w' = 3000$, $m = 7$ feet, $n = 13$, $r = 13$, $s = 7$, $o = 3$, $v = 17$, and $l = 20$.

Then $W = \frac{7000 \times 13 \times 7}{20} = 31\,850$, $\frac{4000 \times 13 \times 7}{20} = 18\,200$, and $w' = \frac{3000 \times 3 \times 17}{20} = 7650$, and let fall perpendic[ular]s thereto, as 3 d, 2 c, and 1 b.

[Co]nnect d, c, and b with A B, and sum of distances of intersections of the[se o]n perpendiculars, from 3, 2, and 1 respectively, will give stress upon [th]e points.

To determine Greatest Stress at Greatest Load.

[St]ress at 3 d $= 31\,850$ " " *2 c* $= 13 : 18\,200 : 7 = 9\,800$	Stress at 1 b $= 17 : 7650 : 3$

$\ldots 00 + \frac{7 \times 13 \times 4000 \times .5}{20} = 52\,100$ *lbs.*, concentrated load at W, and p[er unif]*ormly distributed load of* 4000 lbs.

MECHANICAL POWERS.

Mechanical Power is a compound of *Weight*, or *Force* and *Ve*
it cannot be increased by mechanical means.

The Powers are three in number—viz., Lever, Inclined Plan,
Pulley.

Note.—A Wheel and Axle is a *continuous* or *revolving lever*, a Wedge a dou
clined plane, and a Screw a *revolving* inclined plane.

LEVER.

Levers are straight, bent, curved, single, or compound.

To Compute Length of a Lever.

When Weight and Power are given. Rule.—Divide weight by p
and quotient is leverage, or distance from fulcrum at which power sup
weight.

Or, $\frac{W}{P} = p$. W *representing weight*, P *power*, *and* p *distance of power from ful*

Example.—A weight of 1600 lbs. is to be raised by a power or force of 8
quired length of longest arm of lever, shortest being 1 foot.

$1600 \div 80 = 20$ *feet.*

To Compute Weight that can be raised by a Lev

When its Length, Power, and Position of its Fulcrum are given. Ru
Multiply power by its distance from fulcrum, and divide product by
tance of weight from fulcrum.

Or, $\frac{P\,p}{w} = W$. *w representing distance of weight from fulcrum.*

Example.—What weight can be raised by 375 lbs. suspended from end of a
8 feet from fulcrum, distance of weight from fulcrum being 2 feet?

$375 \times 8 \div 2 = 1500$ *lbs.*

To Compute Position of Fulcrum.

*When Weight and Power and Length of Lever are given, and when
crum is between Weight and Power.* Rule.—Divide weight by powe
1 to quotient, and divide length by sum thus obtained.

Or, $L \div \left(\frac{W}{P} + 1\right) = w$. L *representing entire length of lever.*

Example.—A weight of 2460 lbs. is to be raised with a lever 7 feet long
power of 300; at what part of lever must fulcrum be placed?

$2460 \div 300 = 8.2$, and $8.2 + 1 = 9.2$. Then $7 \times 12 \div 9.2 = 9.13$ *ins.*

When Weight is between Fulcrum and Power. Rule.—Divide le
by quotient of weight, divided by power.

$$\text{Or, } L \div \frac{W}{P} = w.$$

...ute Length of Arm of Lever to whi... Weight is attached.

...r. and Length of Arm of Lever to which Power i...
...—Multiply power by length of arm to whi...
... weight.

$$\text{Or, } \frac{P\,p}{W} = w.$$

ɪPLE.—A weight of 1600 lbs., suspended from a lever, is supported by a power pplied at other end of arm, 20 feet in length; what is length of arm?

$$80 \times 20 \div 1600 = 1 \textit{ foot.}$$

ɛ.—These rules apply equally *When fulcrum (or support) of lever is between and power;* when fulcrum is at one extremity of lever, and power, or weight, ther;† and when arms of lever are equally or unequally bent or curved.*

'ompute Power Required to Raise a given Weight.

en Length of Lever and Position of Fulcrum are given. RULE.—Mul- weight to be raised by its distance from fulcrum, and divide product tance of power from fulcrum.

$$\text{Or, } \frac{W\,w}{p} = P.$$

ᴍPLE.—Length of a lever is 10 feet, weight to be raised is 3000 lbs., and its ce from fulcrum is 2 feet; what is power required?

$$\frac{3000 \times 2}{10 - 2} = \frac{6000}{8} = 750 \textit{ lbs.}$$

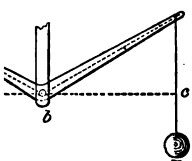
'ompute Length of Arm of Lever to which Power is applied.

en Weight, Power, and Distance of Fulcrum are given. RULE.—Mul- weight by its distance from fulcrum, and divide product by power.

$$\text{Or, } \frac{W\,w}{P} = p.$$

ᴍPLE.—A weight of 400 lbs., suspended 15 ins. from fulcrum, is supported by ɔr of 50, applied at other; what is length of the arm?

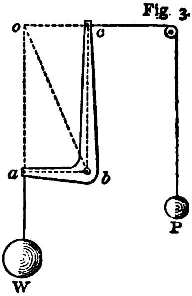
$$400 \times 15 \div 50 = 120 \textit{ ins.}$$

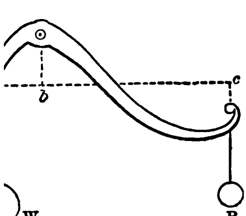


When Arms of a Lever are bent or curved, Distances taken from perpendiculars, drawn from lines of direction of weight and power, must be measured on a line running horizontally through fulcrum, as *a b c*, Figs. 1 and 2.

When Arms of a Lever are at Right Angles, and Power and Weight are applied at a Right Angle to each other, Fig. 3, The moments are computed directly as *a b* to *b c*.

Fig. 3.





Thrust, or pressure on fulcrum, is in this case less than sum of power and weight; and it may be determined by drawing a parallelogram upon the two arms of lever, arms representing inversely their respec- orces. That is, *a b* represents magnitude and directi *c of power P. Diagonal o b* of parallelogram repr *ection of third* force, or thrust upon fulcrum.

* Pressure upon fulcrum is equal to sum of weight and power.
† Pressure upon fulcrum is equal to difference of weight and po

Wheel and Pinion Combinations, or Complex Wheel-work.

Power, multiplied by product of radii or circumferences, or number of teeth of wheels, is equal to weight, multiplied by product of radii or circumferences, or number of teeth or leaves of pinions.

$$\text{Or, } P\,R\,R'\,R'', \text{ etc.}, = W\,r\,r'\,r'', \text{ etc.}$$

NOTE.—Cogs on face of wheel are termed *teeth*, and those on surface of axle are termed *leaves;* the axle itself in this case is termed a *pinion.*

Rack and Pinion.

To Compute Power of a Rack and Pinion.

RULE.—Multiply weight to be sustained by quotient of radius of pinion, divided by radius of crank, and product is power required.

$$\text{Or, } W\,\frac{r}{R} = P.$$

When Pinion on Crank Axle communicates with a Wheel and Pinion. RULE.—Multiply weight to be sustained by quotient of product of radii of pinions, divided by radii of crank and wheel. and product is power required.

$$\text{Or, } W\,\frac{r\,r'}{R\,R'} = P.$$

EXAMPLE.—If radii of pinions of a jack-screw are each one inch; of crank and wheel 10 and 5 ins.; what power will sustain a weight of 750 lbs.?

$$750 \times \frac{1 \times 1}{10 \times 5} = \frac{750}{50} = 15 \textit{ lbs.}$$

INCLINED PLANE.

To Compute Length of Base, Height, or Length.

When any Two of them are given, and when Line of Direction of Power or Traction is Parallel to Face of Plane.—Proceed as in Mensuration or Trigonometry to determine side of a right-angled triangle, any two of these being given.

To Compute Power necessary to Support a Weight on an Inclined Plane.

When Height and Length are given. RULE.—Multiply weight by height of plane, and divide product by length.

$$\text{Or, } \frac{W\,h}{l} = P.$$ *h and l representing height and length of plane.*

EXAMPLE.—What is power necessary to support 1000 lbs. on an inclined plane 4 feet in height and 6 feet in length?

$$1000 \times 4 \div 6 = 666.67 \textit{ lbs.}$$

To Compute Weight that may be Sustained by a given Power on an Inclined Plane.

When Height and Length of Plane are given. RULE.—Multiply power by length of plane, and divide product by height.

$$\text{Or, } \frac{P\,l}{h} = W.$$

EXAMPLE.—What is weight that can be sustained on an inclined plane 5 feet in height and 7 feet in length by a power of 700 lbs.?

$$700 \times 7 \div 5 = 980 \textit{ lbs.}$$

...timating power required to overcome resistance of a body being ...orted upon an inclined plane, and contrariwise, if body is d... ...f body, in proportion of power of plane (i. e., as its length to ... ...ded to resistance, if being drawn up or supported, or to ...

Compute Height or Length of an Inclined Plane.

Then Weight and Power and one of required Elements are given, and n Height is required. RULE.—Multiply power by length, and divide luct by weight.

Then Length is required. RULE.—Multiply weight by height, and divide luct by power.

$$\text{Or, } \frac{P\,l}{W} = h, \text{ and } \frac{W\,h}{P} = l.$$

To Compute Pressure on an Inclined Plane.

ULE.—Multiply weight by length of base of plane, and divide product ength of face.

Or, $\frac{W\,b}{l}$ = *pressure.* *b representing length of base of plane.*

CAMPLE.—Weight on an inclined plane is 100 lbs., base of plane is 4 feet, and th of it 5; required pressure on plane.

$100 \times 4 \div 5 = 80$ *lbs.*

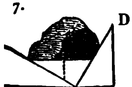
en Two Bodies on Two Inclined Planes sustain each other, as by Connection a Cord over a Pulley, their Weights are directly as Lengths of Planes.

LUSTRATION.—If a weight of 50 lbs. upon an inclined plane, of 10 feet rise in 100 n inclination, is sustained by a weight on another plane of 10 feet rise in 90, t is the weight of the latter?

00 : 90 :: 50 : 45 = *weight that on shortest plane would sustain that on largest.*

Then a Body is Supported by Two Planes, as Fig. 7, pressure upon them will be reciprocally as sines of inclinations of planes.

7.



Thus, weight is as sin. A B D.
Pressure on A B as sin. D B *i*.
Pressure on B D as sin. A B *h*.

Assume angle A B D to be 90°, and D B *i*, 60°; then angle A B *h* will be 30°; and as sines of 90°, 60°, and 30° are respectively .1, .866, and .5, if weight = 100 lbs., then pressures on and B D will be 86.6 and 50 lbs., *centre of gravity of weight assumed to be in its re.*

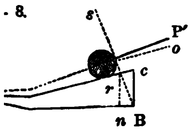
When Line of Direction of Power is parallel to Base of Plane, power is weight as height of plane to length of its base.

Or, P : W :: *h* : *b*.

$$\text{Hence, } P = \frac{W\,h}{b}; \quad W = \frac{P\,b}{h}; \quad h = \frac{P\,b}{W}; \quad b = \frac{W\,h}{P}.$$

When Line of Direction of Power is neither parallel to Face of Plane its Base, but in some other Direction, as P′, Fig. 8, power is to weight e of angle of plane's elevation to cosine of angle which line of power o ction describes with face of plane.

. 8.



Thus, P′ : W :: sin. A : cos. P′ *e c*.
Sin. A : cos. P′ *e c* :: P′ : W.
Cos. P′ *e c* : sin. A :: W : P′.

ILLUSTRATION.—A weight of 500 lbs. is required to be sustained on a plane, angle of elevation of which, *c* A B, is 10°; line of direction of power or traction, P′ *e c*, is 5°; what is sustaining power required?

Cos. P′ *e c* (5°) = .996 19 : sin. A (10°) = .173 65

r, draw a line, B *s*, perpendicular to direction of se line (at back of plane), and intersection. e determine length and height (*n r*) of the plane.

Differential Screw.

When a hollow screw revolves upon one of less diameter and pitch (as designed by Mr. Hunter), effect is same as that of a single screw, in which the distance between threads is equal to difference of distances between threads of the two screws.

Therefore power, to effect or weight sustained, is as difference between distances of threads of the two screws to circumference described by power.

ILLUSTRATION.—If external screw has 20 threads, and internal one 21 threads to a pitch of 1 inch, and power applied describes a circumference of 35 ins., the result of power is as $\frac{1}{21} \infty \frac{1}{20} = \frac{1}{420}$, or .002 38. Hence $\frac{35}{.00238} = 14\,706$.

PULLEY.

PULLEYS are designated as *Fixed* and *Movable*, according as cord is passed over a fixed or a movable pulley. A *movable* pulley is when cord passes through a second pulley or block in suspension; a single movable pulley is termed a *runner;* and a combination of pulleys is termed a *system of pulleys*.

A *Whip* is a single cord over a fixed pulley.

To Compute Power Required to Raise a given Weight.

When Number of Parts of Cord supporting Lower Block are given, and when only one Cord or Rope is used. RULE.—Divide weight to be raised by number of parts of cord supporting lower or movable block.

Or, $W \div n = P$. Or, $n\,P = W$. *n representing number of parts of cord supporting lower block.*

EXAMPLE.—What power is required to raise 600 lbs. when lower block contains six sheaves?

When Cord is attached to Upper or Fixed Block.

$\frac{600}{6 \times 2} = 50$ *lbs. = weight ÷ number of parts of rope sustaining lower block.*

When Cord is attached to Lower or Movable Block.

$\frac{600}{6 \times 2 + 1} = 46.15$ *lbs. = weight ÷ number of parts of rope sustaining lower block.*

To Compute Weight a given Power will Raise.

When Number of Parts of Cord supporting Lower Block are given. RULE.—Multiply power by number of parts of cord supporting lower block.

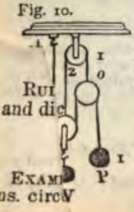
Or, $P\,n = W$.

To Compute Number of Cords necessary to Sustain Lower Block.

When Weight and Power are given. RULE.—Divide weight by power.

Or, $W \div P = n$.

Fig. 10.

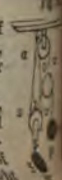


When more than one Cord is used.

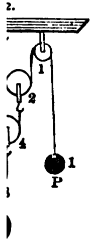
In a Spanish Burton, Fig. 10, where ends of one cord, *a* P, are fastened to support and power, and ends of the other, *c o*, to lower and upper blocks, weight is to power as 4 to 1.

In another, Fig. 11, where there are two cords, *a* and *o*, two movable pulleys, and one fixed pulley, with ends of one rope fastened to support and upper movable pulley, and ends of other fastened to lower block and power, weight is to power as 5 to 1.

Fig. 11.



Compound or Fast and Loose Pulleys.



When Cord is attached to Fixed Block, Fig. 12. RULE.—Multiply power by the power of 2, of which the index is number of movable pulleys.

Or, $P\,2^n = W$.

Or, Multiply power successively by 2 for each pulley.

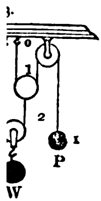
EXAMPLE 1.—What weight will one pound support in a system of three movable pulleys, the cords being connected to a fixed block on Fig. 12. $1 \times 2^3 = 8$ *lbs.*

EXAMPLE 2.—What would a like power support, fixed block being made movable and cord attached thereto?

$1 \times 2^4 - 1 = 15$ *lbs.*

If fixed pulleys were substituted for hooks *a b c*, Fig. 12, power would be increased threefold; hence $1 \times 3^3 = 27$.

System of Pulleys, Figs. 13 and 14, *with any Number of Cords, o o, e e, Ends being fastened to Support.*



$W \div 2^n = P$; $2^n \times P = W$; $\frac{W}{P} = 2^n$. *n representing number of distinct cords.*

ILLUSTRATION.—What weight will a power of 1 lb. sustain in a system of two movable pulleys and two cords?

$1 \times 2 \times 2 = 4$ *lbs.*

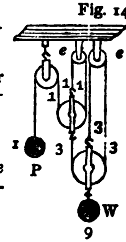


Fig. 14.

When fixed Pulleys, e e, are used in Place of Hooks, to Attach Ends of Rope to Support.—Fig. 14.

$W \div 3^n = P$; $3^n \times P = W$; $W \div P = 3^n$.

…STRATION.—What weight will a power of 5 lbs. sustain with two movable and fixed pulleys, and two cords? $5 \times 3 \times 3 = 45$ *lbs.*

… Ends of Cord or Fixed Pulleys are fastened to Weight, as by an Inver… of the last Figures, putting Supports for Weights, and contrariwise.—…s. 13 and 14.

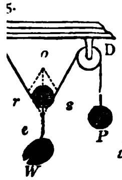
Fig. 13. $\frac{W}{(2^n - 1)} = P$; $(2^n - 1)\,P = W$; $\frac{W}{P} = (2^n - 1)$.

Fig. 14. $\frac{W}{(3^n - 1)} = P$; $(3^n - 1)\,P = W$; $\frac{W}{P} = (3^n - 1)$.

…STRATION.—What weight will a power of 1 lb. sustain in a system of two mov… …ulleys and two cords, and one of two movable and two fixed pulleys and two …?

$1 \times 2 \times 2 - 1 = 3$ *lbs.* $1 \times 3 \times 3 - 1 = 8$ *lbs.*

…en Cords sustaining Pulleys are not in a Vertical Direction.—Fig. 15.



e o, Fig. 15, is vertical line through which weight bears, and from *o* draw *o r*, *o s* parallel to D *e* and A *e*.

Forces acting at *e* are represented by lines *e s*, *e r*, and *e o*; and as tension of every part of cord is same, and equal to power P, sides *o s* and *o r* of parallelogram must be equal, and therefore diagonal *e o* divides the angle *r o s* into two equal portions. Hence the weight will always fall into the position in which the two parts of cord A e and e D will be equ… inclined to vertical line, and it will bear to power same … as *e o* to *e s*.

Therefore W : P :: 2 cos. .5 *e* : 1. *e* representing angle A…

…$\times$ *cos.* .5 *e* = W. That is, twice power, multiplied by cosine of half … *…t point of suspension of weight*, is equal to weight.

Illustration.—What weight will be sustained by a power of 5 lbs., wi lique movable pulley, Fig. 15, having an angle, A *e* D, of 30°?

$$5 \times 2 \times .96593 = 9.6593 \text{ lbs.} = \textit{twice power} \times \cos. 15^\circ.$$

When Direction of Cord is Irregular, Weight not resting in Centr

$\frac{P}{W} = \frac{\sin. a}{\sin. (a+b)}$; $\frac{P \sin. (a+b)}{\sin. a} = W$; $\frac{W \sin. a}{\sin. (a+b)} = P$. *a and b re greater and lesser angles of cord at e.*

METALS.

ALLOYS AND COMPOSITIONS.

Alloy is the proportion of a baser metal mixed with a finer o as copper is mixed with gold, etc.

Amalgam is a compound of Mercury and a metal—a soft

Compositions of copper contract in admixture, and all *Amalg* pand.

In manufacture of Alloys and Compositions, the less fusible should be melted first.

In Compositions of Brass, as proportion of Zinc is increase malleability decreased.

Tenacity of Brass is impaired by addition of Lead or Tin.

Steel alloyed with one five-hundredth part of Platinum, or Si rendered harder, more malleable, and better adapted for cutting ments.

Specific gravity of alloys* does not follow the ratios of those o components; it is sometimes greater and sometimes less than the

Composition for Welding Cast Steel.

Borax, 91 parts; Sal-ammoniac, 9 parts. Grind or pound them roughly to fuse them in a metal-pot over a clear fire, continuing heat until all spume h appeared from surface. When liquid is clear, pour composition out to cool a crete, and grind to a fine powder; then it is ready for use.

To use this composition, the steel to be welded should be raised to a bright heat; then dip it in the welding powder, and again raise it to a like heat as b it is then ready to be submitted to the hammer.

Fusible Compounds.

Compounds.	Zinc.	Tin.	Lead.	Bismuth.	Cad
Rose's, fusing at 200°	—	25	25	50	-
Fusing at less than 200°	33.3	—	33.3	33.4	-
Newton's, fusing at less than 212°.	—	19	31	50	-
Fusing at 150° to 160°	—	12	25	50	13

Solders.

Solder is an alloy used to make joints between metals, and it mus more fusible than the metals it is designed to unite, and it is distingui as *hard* and *soft*, according to the temperature of its fusing.

The addition of a small portion of Bismuth increases its fusibility.

* For a table of Alloys, having densities different from a mean of their components, nual, London, 1877, page 201.

Alloys and Compositions.

	Copper.	Zinc.	Tin.	Nickel.	Lead.	Antimony.	Bismuth.	Aluminum.
tan	55	24	—	21	—	—	—	—
num, brown	95	—	—	—	—	—	—	5
t's metal *	3.7	—	89	—	—	7.3	—	—
common	84.3	5.2	10.5	—	—	—	—	—
"	75	25	—	—	—	—	—	—
" hard	79.3	6.4	14.3	—	—	—	—	—
instruments	92.2	—	7.8	—	—	—	—	—
locomot. bearings	90	1	9	—	—	—	—	—
Pinchbeck	80	20	—	—	—	—	—	—
red Tombac	88.8	11.2	—	—	—	—	—	—
rolled	74.3	22.3	3.4	—	—	—	—	—
Tutenag	50	31	—	19	—	—	—	—
very tenacious	88.9	2.8	8.3	—	—	—	—	—
wheels, valves	90	—	10	—	—	—	—	—
white	10	80	10	—	—	—	—	—
"	3	90	—	—	—	7	—	—
"	7	—	—	—	46	47	—	—
wire	67	33	—	—	—	—	—	—
yellow, fine	66	34	—	—	—	—	—	—
nia metal	—	—	25	—	—	25	—	—
When fused add	—	—	—	—	—	25	25	—
e, red	87	13	—	—	—	—	—	—
"	86	11.1	2.9	—	—	—	—	—
yellow	67.2	31.2	1.6	—	—	—	—	—
Gun metal, large	90	—	10	—	—	—	—	—
" small	93	—	7	—	—	—	—	—
" soft	95	—	5	—	—	—	—	—
Cymbals	80	—	20	—	—	—	—	—
Medals	93	—	7	—	—	—	—	—
Statuary	91.4	5.5	1.4	—	1.7	—	—	—
se silver	58.1	17.2	—	11.6	—	—	2 Silver.	Cobalt of Iron. 11.1
white copper	40.4	25.4	2.6	31.6	—	—	—	—
h bells	80	5.6	10.1	—	4.3	—	—	—
"	69	—	31	—	—	—	—	—
, Musical bells	87.5	—	12.5	—	—	—	—	—
bells	72	—	26.5	—	—	—	—	Iron. 1.5
n silver	33.3	33.4	—	33.3	—	—	—	—
"	40.4	25.4	—	31.6	—	—	—	2.6
" fine	49.5	24	—	24	—	—	—	2.5
	81.6	—	18.4	—	—	—	—	—
bells	77	—	23	—	—	—	—	—
bushes	80	—	20	—	—	—	—	—
nery bearings	87.5	—	12.5	—	—	—	—	—
" hard	77.4	7	15.6	—	—	—	—	—
that expands in ing	—	—	—	—	75	16.7	Bismuth. 8.3	—
metal, 10 oz. lead	60	40	—	—	—	—	—	—
r, best	—	—	86	—	—	14	—	—
	—	—	80	—	20	—	—	—
ing metal	56	45	—	—	—	—	—	—
lum "	66	—	22	—	—	—	—	Arsenic. 12
"	50	21	29	—	—	—	—	—
opic mirrors	66.6	—	33.4	—	—	—	—	—
er †	33.4	—	66.6	—	—	—	—	—
metal and stereo- plates	—	—	—	—	75	25	—	—
	—	—	—	—	87.5	12.5	—	—
metal	7.4	7.4	28.4	—	—	56.8	—	
" *hard*	69.8	25.8	4.4	—	—	—	—	
	73	12.3	Magnesia...... 4.4; Sal-ammoniac . 2.5			Cream of tar; Quicklime.		

e 636 for directions.

† For adding small quantities of co

Solders.

	Copper.	Tin.	Lead.	Zinc.	Silver.	Bismuth.	Gold.	Cadmium.	Antimony.
Tin	—	25	75	—	—	—	—	—	—
"	—	58	16	—	—	16	—	—	10
" coarse, melts at 500°	—	33	67	—	—	—	—	—	—
" ordi'y, melts at 360°	—	67	33	—	—	—	—	—	—
Spelter, soft	50	—	—	50	—	—	—	—	—
" hard	65	—	—	35	—	—	—	—	—
Lead	—	33	67	—	—	—	—	—	—
Steel	13	—	—	5	82	—	—	—	—
Brass or Copper	50	—	—	50	—	—	—	—	—
Fine brass	47	—	—	47	6	—	—	—	—
Pewterers' or Soft	—	33	45	—	—	22	—	—	—
" "	—	50	25	—	—	25	—	—	—
Plumbers' pot-metal	—	33	67	—	—	—	—	—	—
" coarse	—	25	75	—	—	—	—	—	—
" fine	—	67	33	—	—	—	—	—	—
" fusible	—	50	50	—	—	—	—	—	—
" very "	—	25	25	—	—	50	—	—	—
Gold	4	—	—	—	7	—	89	—	—
" hard	66	—	—	34	—	—	—	—	—
" soft	—	66	34	—	—	—	—	—	—
Silver, hard	20	—	—	—	80	—	—	—	—
" soft	12	—	—	—	67	—	—	21	—
Pewter	—	40	20	—	—	40	—	—	—
Iron	66	—	—	33	—	—	—	—	1
Copper	53	47	—	—	—	—	—	—	—

A Plastic Metallic Alloy.—See Journal of Franklin Institute, vol. xxxix., page 55 for its composition and manufacture.

Soldering Fluid for use with Soft Solder.

To 2 fluid oz. of Muriatic acid add small pieces of Zinc until bubbles cease to rise. Add .5 a teaspoonful of Sal-ammoniac and two fluid oz. of Water.

By the application of this to Iron or Steel, they may be soldered without their surfaces being previously tinned.

Fluxes for Soldering or Welding.

Iron	Borax.	Zinc	Chloride of zinc.
Tinned iron	Resin.	Lead	Tallow or resin.
Copper and Brass	Sal-ammoniac.	Lead and tin	Resin and sweet oil.

Babbitt's Anti-attrition Metal.

Melt 4 lbs. Copper; add by degrees 12 lbs. best Banca tin, 8 lbs. Regulus of antimony, and 12 lbs. more of Tin. After 4 or 5 lbs. Tin have been added, reduce heat to a dull red, then add remainder of metal as above.

This composition is termed *hardening;* for *lining,* take 1 lb. of this hardening, melt with it 2 lbs. Banca tin, which produces the lining metal for use. Hence, the proportions for lining metal are 4 lbs. of copper, 8 of regulus of antimony, and of tin.

Brass.

Brass is an alloy of copper and zinc, in proportions varying with purpose of metal required, its color depending upon the proportions.

It is rendered brittle by continued impacts, more malleable than copper when cold, but is impracticable of being forged, as its zinc melts at a low perature.

fusibility is governed by its proportion of zinc; a small quantity rus gives it fluidity.

Bronze.

nze is an alloy of copper and tin; it is harder, more fusible, and er than copper. It is usually known as *Gun-metal.*

ninum Bronze contains 90 to 95 per cent. of copper, and 5 to 10 per luminum.

phor Bronze contains copper and tin and a small proportion of phos-. It wears better than bronze.

IRON.

eign substances which iron contains modify its essential proper. *Carbon* adds to its hardness, but destroys some of its qualities, roduces Cast Iron or Steel, according to proportion it contains. .25 per cent. renders it malleable, .5 steel, 1.75 is limit of weld-eel, and 2 is lowest limit of cast iron. *Sulphur* renders it fusible, lt to weld, and brittle when heated, or "*hot short.*" *Phosphorus* rs it "*cold short,*" but may be present in proportion of .002 to without affecting injuriously its tenacity. *Antimony*, *Arsenic*, and r have same effect as sulphur, the last in a greater degree. *Sili-* nders it hard and brittle. *Manganese*, in proportion of .02, ren-t "*cold short,*" and *Vanadium* adds to its ductility.

Cast Iron.

cess of making Cast Iron depends much upon description of fuel used; er charcoal, coke, bituminous, or anthracite coals. A larger yield from furnace, and a great economy in fuel, are effected by use of a *hot blast.* reater heat thus produced causes the iron to combine with a larger tage of foreign substances.

t Iron for purposes requiring great strength should be smelted with *blast.* *Pig-iron*, according to proportion of carbon which it contains, ided into *Foundry Iron* and *Forge Iron*, latter adapted only to conver-to malleable iron; while former, containing largest proportion of car-n be used either for castings or bars.

h temperature in melting injures gun-metal.

re are many varieties of Cast Iron, differing by almost insensible ; the two principal divisions are *gray* and *white*, so termed from f their fracture. Their properties are very different.

y Iron is softer and less brittle than white; it is in a slight degree ble and flexible, and is insonorous; it can easily be drilled or turned, oes not resist the file. It has a brilliant fracture, of a gray, or some-a bluish-gray, color; color is lighter as grain becomes closer, and its ess increases. It melts at a lower heat than white, and preserves its y longer. Color of the fluid metal is red, and deeper in proportion as eat is lower; it does not adhere to the ladle; it fills molds well, con-less, and contains fewer cavities than white; edges of its castings arp, and surfaces smooth and convex. It is used for machinery and ace where the pieces are to be bored or fitted. Its tenacity and specific y are *diminished* by annealing.

ite Iron is very brittle and sonorous; it resists file and chisel, and is tible of high polish; surface of its castings is concave; fracture pre-*a silvery appearance*, generally fine grained and compact, so *ng or lamellar.* When melted it is white, throws off a gre *ks, and its qualities* are the reverse of those of gray iron; *uitable for machinery purposes.* Its tenacity is increc *ravity diminished*, by annealing.

Best quality of iron has greatest elasticity.

Tests.—It will not blacken if exposed to nitric acid. Long si a fracture denote a soft and strong metal; short black fibres de refined metal, and a fine grain denotes hardness and conditio "cold short." Coarse grain with bright and crystallized fractu colored spots, also denotes "cold short" and brittle metal, workin welding well. Cracks upon edges of a bar, etc., indicate "hot sl iron heats readily, is worked easily, and throws off but few sparl

A high breaking strain may not be conclusive as to quality, ε due to a hard, elastic metal, or a low one may be due to great so

When iron is fractured suddenly, a crystalline surface is pı when gradually, a fibrous one. Breaking strain of iron is increε ing it and suddenly cooling it in water. Iron exposed to a weld heat and not reduced by hammering or rolling is weakened.

Specific gravity of iron is a good indication of its quality, as very correctly its relative degree of strength.

LEAD.

Sheet Lead is either *Cast* or *Milled*, the former in sheets 16 ı length and 6 feet in width; the latter is rolled, is thinner than is more uniform in its thickness, and is made into sheets 25 t length, and from 6 to 7.5 feet in width.

Soft or Rain Water, when aerated, Silt of rivers, Vegetable m: Mortar, and Vitiated Air will oxidize lead. The waters whi greatest effect on it are the purest and most highly oxygenated, ı nitrates, and chlorides, and those which act with least effect are ı tain carbonate and phosphate of lime.

Coating of Pipes, except with substances insoluble in water, and Sulphide of lead, is objectionable.

Lead-encased Pipes.—An inner pipe of tin is encased in one oi

ed Steel, or Steel of Cementation, is prepared by direct combination of carbon. For this purpose, iron in bars is put in layers, alternating dered charcoal, in a close furnace, and exposed for 7 or 8 days to emperature, and then put to cool for a like period. The bars, on ten out, are covered with blisters, have acquired a brittle quality, bit in fracture a uniform crystalline appearance. The degree of ation is varied according to purposes for which the steel is intended, very best qualities of iron are used for the finest kinds of steel.

Steel is made from blistered steel moderately heated and subjected of a tilt hammer, by which means its tenacity and density are in-

Steel is made from blistered or natural steel, refined by piling thin fagots, which are brought to a welding heat in a reverberatory and hammered or rolled again into bars; this operation is repeated mes to produce finest kinds of shear steel, which are distinguished rms of *Half shear*, *Single shear*, and *Double shear*, or steel of 1, 2, or etc., according to number of times it has been piled.

Steel is blister steel heated to an orange red color and rolled or d.

Crucible Steel is made by breaking blistered steel into small pieces ing it in close crucibles, from which it is poured into iron molds: hen reduced to a bar by hammering or rolling. Cast steel is best steel, and best adapted for most purposes: it is known by a very , and close grain, and a silvery, homogeneous fracture: it is very id acquires extreme hardness, but is difficult to weld without use . Other kinds of steel have a similar appearance to cast steel, but coarser and less homogeneous: they are softer and less brittle, and e readily. A fibrous or lamellar appearance in fracture indicates fect steel. A material of great toughness and elasticity, as well as is made by forging together steel and iron, forming the celebrated *d Steel*, which is used for sword-blades, springs, etc.: damask ap- of which is produced by a diluted acid, which gives a black tint to while the iron remains white.

ast steel, breaking strength is greater across fibres of rolling than n.

Process is an improvement on this method, and consists in adding to etal a small quantity of carburet of manganese.

s Process consists in adding nitrate of soda to molten pig-iron, in order to rbon and silica.

s Process.—Malleable iron is melted in crucibles with oxide of manganese oal.

d Steel is produced by arresting the puddling in the manufacture rought iron before all the carbon has been removed, the small of carbon remaining, .3 to 1 per cent., being sufficient to make an teel.

Steel contains from .2 to .5 per cent. of carbon: when more is pres- ermed *Hard Steel*.

er Steel is made direct from pig-iron. The carbon is first removed, o obtain pure wrought iron, and to this is added the exact quantity required for the steel. The pig should be free from sulphur us. It is melted in a blast or cupola, and run into a con ed iron vessel suspended on hollow trunnions and lined w clay), where it is subjected to an air blast for a period of der to dispel the carbon, after which from 5 to 10 per cent. added.

slag, and the carbon, combining with oxygen, escapes as carboni induces a powerful ebullition.

Modification of this process.—The ore is treated in a separate rotat with carbonaceous material, and converted into balls of malleable iroi transferred from the rotatory to the bath of the steel-melting furnace.

This process is adapted to the production of steel of a very high qual the sulphur and phosphorus of the ore are separated from the metal in t furnace.

Siemen's-Martin Process.—Scrap-iron or steel is gradually a highly heated condition to a bath of about .25 its weight, of hig pig, and melted. Samples are occasionally taken from the bath, i ascertain the percentage of carbon remaining in the metal, and oi in small quantities, in order to reduce the carbon to about .1 per c

At this stage of the process, siliceous iron, spiegeleisen, or ferro-r is added in such proportions as are necessary to produce steel of th degree of hardness. The metal is then tapped into a ladle.

Landore-Siemen's Steel is a variety of steel made by the *Modij Siemen's Process.* Its great value is due to its extreme ductili having nearly like strength in both directions of its plates.

Whitworth's Compressed Steel is molten steel subjected to a p about 6 tons per square inch, by which all its cavities are dispelle compressed to about .875 of its original volume, its density and st ing proportionately increased.

Chrome and Tungsten Steel are made by adding a small pero Chromium or Tungsten to crucible steel, the result producing a great hardness and tenacity, suitable for tools, such as drills, etc.

Homogeneous Steel is a variety of cast steel containing .25 pe carbon.

' the crystalline structure takes place entirely in cooling, between nd *b*; when temperature sinks below *b* there is no change of strucsful forging, therefore, heated ingot, after it is taken out of furnace, s quickly as practicable, so as not to leave any spot untouched by the steel might crystallize quietly, as formation of crystals should l the steel should be kept in an amorphous condition until temelow point *b*.

ıperature, if piece is cooled in quiet, mass will no longer be disposed t will possess great tenacity and homogeneousness of structure. forged at temperatures lower than *b*, its crystals or grains, being ch other, change their shapes, becoming elongated in one direction, n another; while density and tensile strength are considerably inailable hammer-power is only sufficient for treatment of small steel bject of preventing coarse crystalline structure in large forgings nd more certainly effected, if, after having given forging desired ıre be altered to an homogeneous amorphous condition by heating ure somewhat higher than *b*, and the condition be fixed by rapid perature lower than *b*, the piece should then be allowed to finish *y*, so as to prevent, as far as practicable, internal strains due to ual contraction.

el with *Silver*, *Platinum*, *Rhodium*, and *Aluminum* have been iew to imitating Damascus steel, Wootz, etc., and improving ome finer kinds of surgical and other instruments.

'*Steel*.—After being tempered it is not easily broken; it welds ot crack or split; bears a very high heat, and preserves the ırdening after repeated working.

nd Tempering.—Upon these operations the quality of manuı a great measure depends.

ı effected by heating steel to a cherry-red, or until scales of ıed on surface, and plunging it into a cooling liquid; degree pends upon heat and rapidity of cooling. Steel is thus renas to resist files, and it becomes at same time extremely e of heat, and temperature and nature of cooling medium, ı with reference to quality of steel and purpose for which it Cold water gives a greater hardness than oils or like subvet-iron scales, or cinders, but an inferior degree of hardness y acids. Oil, tallow, etc., prevent cracks caused by too rapid r the heat at which steel becomes hard, the better.

-Steel in its hardest state being too brittle for most purposes, rength and elasticity are obtained by tempering—or "*letting* ."—which is performed by heating hardened steel to a certain ing it quickly. Requisite heat is usually ascertained by color of the steel assumes from film of oxide thus formed. Degrees h these several colors correspond are as follows:

nt yellow.. ıw color....	Suitable for hard instruments; as hammer-faces, drills, lancets, razors, etc.
low........ color.......	For instruments requiring hard edges without elasticity; as shears, scissors, turning tools, penknives, etc.
with purple	For tools for cutting wood and soft metals; such as plane-irons, saws, knives, etc.
ue.........	For tools requiring strong e... ...t extreme hardness; as cold-chisels, a...
blue, verg-	For spring-temper, which wi... ...ing, as saws, sword-blades, etc.

ted to a higher temperature than this, e... *ved.*

ıg strain may not be conclusive as to ... *stic metal*, or a low one may be due to ...

TIN.

TIN is more readily fused than any other metal, and oxidizes ve
Its purity is tested by its extreme brittleness at high temperatu
Tin plate is iron plate coated with tin.
Block Tin is tin plate with an additional coating of tin.

ZINC.

ZINC, if pure, is malleable at 220°; at higher temperatures, suc it becomes brittle. It is readily acted upon by moist air, and wh of oxide is formed, it protects the surface from further action. W ever, the air is acid, as from the sea or large towns, it is readily o destruction.

Iron, Copper, Lead, and Soot are very destructive of it, in conse the voltaic action generated, and it should not be in contact with c water or acid woods.

The best quality, as that known as "Vielle Montagne," is compos .995, iron .004, and lead .001. Its expansion and contraction by d of temperature is in excess of that of any other metal.

STRENGTH OF MODELS.

The forces to which Models are subjected are,

1. To draw them asunder by *tensile* stress. 2. To break them *verse* stress. 3. To crush them by *compression.*

sistance in a model to crushing increases directly as its dimensions; is stress increases as cubes of dimensions, a model is stronger than the ture, inversely as the squares of their comparative magnitudes.

ence, greatest magnitude of a structure is ascertained by taking square of quotient, as obtained by preceding rule, instead of quotient itself.

AMPLE.—If greatest weight which a column in a model can sustain is 26 lbs., t is required to bear only 4 lbs.; height of column being 18 ins., what should ight of it in structure?

$\left(\frac{26}{4}\right) = \sqrt{6.5} = 2.55$, and $2.55 \times 18 = 45.9$ *ins., height of column in structure.*

when length or height and breadth are retained, and it is required to to the beam, etc., such a thickness or depth that it will not break in con- ence of its increased dimensions,

en $\sqrt{\left(\frac{26}{4}\right)} = \sqrt{6.5} = 2.55$, which, $\times$ square of relative size of model = *thick- required.*

Compute Resistance of a Bridge from a Model.

$$n^2 W - \left[\frac{n^2}{2}(n-1)\,w\right] = \textit{load bridge will bear in its centre.}$$

AMPLE.—If length of the platform of a model between centres of its repose the piers is 12 feet, its weight 30 lbs., and the weight it will just sustain at its e 350 lbs., the comparative magnitudes of model and bridge as 20, and actual a of bridge 240 feet; what weight will bridge sustain?

$$20^2 \times 350 - \left[\frac{400}{2} \times (20-1) \times 30\right] = 140\,000 - 3800 \times 30 = 26\,000 \textit{ lbs.}$$

MOTION OF BODIES IN FLUIDS.

a body move through a fluid at rest, or fluid move against body at resistance of fluid against body is as square of velocity and density iid; that is, $R = d\,v^2$. For resistance is as quantity of matter or cles struck, and velocity with which they are struck. But quan- or number of particles struck in any time are as velocity and density uid; therefore, resistance of a fluid is as density and square of ity.

$= h$, and $\frac{a\,d\,v^2}{2\,g} = R$. *h representing height due to velocity, d density of fluid, resistance or motive force.*

sistance to a plane is as plane is greater or less, and therefore resistance plane is as its area, density of medium, and square of velocity; that is, $a\,d\,v^2$.

otion is not perpendicular, but oblique, to plane or to face of body in any , sine of which is s to radius 1; then resistance to plane, or force of against plane, in direction of motion, will be diminished in triplicate of radius to sine of angle of inclination, or in ratio of 1 to s^3.

ce, $\frac{a\,d\,v^2\,s^3}{2\,g} = R$, and $\frac{a\,d\,v^2\,s^3}{2\,g\,w} = F$. *w representing weight of ing force.*

gression of a solid floating body, as a boat in a channel *ise to a displacement* of water surface, which advances *in direction of* body, and this undulation is termed *nt.*

Resistance of a fluid to progression of a floating body increases as velocity of body attains velocity of wave of displacement, and it is greatest when the two velocities are equal.

In the motion of elastic fluids, it appears from experiments that oblique action produces nearly same effect as in motion of water, in the passage of curvatures, apertures, etc.

Resistance to an Area of One Sq. Foot moving through Water, or Contrariwise.

Angle of Surface with Plane of Current.	*Pressure per Sq. Foot for following Velocities per Foot per Minute.* 120	240	480	900	Angle of Surface with Plane of Current.	*Pressure per Sq. Foot for following Velocities per Foot per Minute.* 120	240	480	900
°	Lbs.	Lbs.	Lbs.	Lbs.	°	Lbs.	Lbs.	Lbs.	Lbs.
6	.09	.359	1.435	5.046	45	2.66	10.639	42.557	[illegible]
8	.133	.53	2.122	7.459	50	2.995	11.981	47.923	[illegible]
9	.156	.624	2.496	8.775	55	3.249	12.995	51.979	[illegible]
10	.179	.718	2.87	10.091	60	3.455	13.822	55.286	[illegible]
15	.355	1 42	5.678	19.963	65	3.607	14.43	57.72	[illegible]
20	.608	2.434	9.734	34.222	70	3.728	14.914	59.654	[illegible]
25	94	3 76	15.038	52.869	75	3.81	15.241	60.965	[illegible]
30	1.353	5 413	21.653	76.123	80	3.857	15.428	61.714	[illegible]
35	1.798	7.192	28.766	101.132	85	3.892	15.569	62.275	[illegible]
40	2.258	9 032	36.13	127.018	90	3.9	15.6	62.4	[illegible]

Resistance to a plane, from a fluid acting in a direction perpendicular to its face, is equal to weight of a column of fluid, base of which is plane and altitude equal to that which is due to velocity of the motion, or through which a heavy body must fall to acquire that velocity.

Resistance to a plane running through a fluid is same as force of fluid in motion with same velocity on plane at rest. But force of fluid in motion is equal to weight or pressure which generates that motion, and this is equal to weight or pressure of a column of fluid, base of which is area of the plane, and its altitude that which is due to velocity.

ILLUSTRATION.—If a plane 1 foot square be moved through water at rate of 32.166 feet per second, then $\frac{32.166^2}{64.333} = 16.083$, space a body would require to fall to acquire a velocity of 32.166 feet per second; therefore 1×62.5 (weight of a cube foot of water) $\times \frac{32.166^2}{64.333} = 1005$ *lbs.* = *resistance of plane.*

Resistance of different Figures at different Velocities in Air.

Velocity per Second.	Cone. Vertex.	Cone. Base.	Sphere.	Cylinder.	Hemisphere. Round.	Velocity per Second.	Cone. Vertex.	Cone. Base.	Sphere.	Cylinder.	Hemisphere. Round.
Feet.	Oz.	Oz.	Oz.	Oz.	Oz.	Feet.	Oz.	Oz.	Oz.	Oz.	Oz.
3	.028	.064	.027	.05	.02	12	.376	.85	.37	.826	[illegible]
4	.048	109	.047	.09	.039	14	.512	1.166	.505	1.145	[illegible]
5	.071	162	.068	.143	.063	15	.589	1.346	.581	1.327	[illegible]
8	.168	382	.162	.36	.16	16	.673	1.546	.663	1.526	[illegible]
9	.211	.478	.205	.456	.199	18	.858	2.002	.848	1.986	[illegible]
10	.26	.587	.255	.565	.242	20	1.069	2.54	1.057	2.528	[illegible]

Diame [illegible] all the figures was 6.375 ins., and altitude of the cone 6.625 ins.

A[illegible] cone and its axis is, consequently, 25° 42′ nearly.

[illegible]e, several practical inferences may be drawn.

[illegible]s is nearly as surface, increasing but a very little there[illegible] greater surfaces.

2. Resistance to same surface is nearly as square of velocity, but gradually increasing more and more above that proportion as velocity increases.

3. When after parts of bodies are of different forms, resistances are different, though fore parts be alike.

4. The resistance on base* of a cone is to that on vertex nearly as 2.3 to And in same ratio is radius to sine of angle of inclination of side of cone its path or axis. So that, in this instance, resistance is directly as sine angle of incidence, transverse section being same, instead of square of sine.

Resistance on base of a hemisphere is to that on convex side nearly as to 1, instead of 2 to 1, as theory assigns the proportion.

Sphere.—Resistance to a sphere moving through a fluid is but half resistance to its great circle, or to end of a cylinder of same diameter, moving h an equal velocity, being half of that of a cylinder of same diameter.

$\sqrt{2\,g \times \frac{4}{3}\,d \times \frac{N-n}{n}} = V$. *d representing diameter of sphere, and* N *and n* specific *gravities of sphere and resisting fluid.*

$\times \frac{4}{3}\,d = S$. S *representing space through which a sphere passes while acquiring its maximum velocity, in falling through a resisting fluid.*

ILLUSTRATION.—If a ball of lead 1 inch in diameter, specific gravity 11.33, be set in water, specific gravity 1, what is greatest velocity it will attain in descending and what space will it describe in attaining this velocity?

$$g = 32.166, \quad d = \frac{1}{12}\text{ foot}, \quad N = 11.33, \text{ and } n = 1.$$

Then $\sqrt{2 \times 32.166 \times \frac{4}{3} \text{ of } \frac{1}{12} \times \frac{11.33-1}{1}} = \sqrt{7.148 \times 10.33} =$

Hence, $\frac{11.33}{1} \times \frac{4}{3} \text{ of } \frac{1}{12} = 1.259$ *feet.* $\frac{3\,n\,v^2}{8\,g\,N\,d} = f =$ *retardive force* $= \frac{v^2}{2\,g\,s}$.

Cylinder. $\frac{n\,a\,v^2}{2\,g} = R$, and $\frac{n\,a\,v^2}{2\,g\,w} = f$. *a representing area or p r², and* weight of body.*

ILLUSTRATION.—Assume $a = 32$ sq. feet, $v = 10$ feet per second, and $n = .0012$.

Then $\frac{.0012 \times 32 \times 10^2}{64.33} = .06$ *of a cube foot of water* $= .06$ of $62.5 = 3.75$ *lbs.*

Conical Surface. $\frac{n\,a\,v^2\,s^3}{2\,g} = R$, also $\frac{n\,p\,d^2\,v^2\,s^2}{8\,g} = R$, and $\frac{n\,p\,d^2\,v^2\,s^2}{8\,g\,w}$ *f. s representing sine of inclination, and a convex surface of cone.*

Curved End as a Sphere or Hemispherical End. $\frac{p\,n\,v^2\,d^2}{16\,g}$ R, and **Circle** .5 *of spherical end.*

In general, when n is to water as a standard, result is in cube feet of water, if s in sq. feet; and in cube ins. of water, if a is in sq. ins., v in ins., and g in ins. If n is given in lbs. in a cube foot, a is in sq. feet, v and g are in feet, result is in lbs.

To Compute Altitude of a Column of Air, Pressure of which shall be equal to Resistance of a Bo[dy mo]ving through it, with any Velocity.

$\times \frac{r}{a} = x =$ *altitude in feet.* $a\,x =$ *volume of column in feet, and* ...*nces. a representing area of section of* body, similar to an... ...*lar to direction of motion, r resistance to* velocity in table, an... *column of air, base of which is a, and pressure r.*

*This is a refutation of the popular assertion that a taper spar can be towed in ...e is foremost.

When $a = \frac{2}{9}$ of a foot, as in all figures in table, x becomes $\frac{15}{4} r$ when r = re*sistance in table to similar body.*

ILLUSTRATION.—Assume convex face of hemisphere resistance = .634 oz. at a velocity of 16 feet per second.

Then $r = .634$, and $x = \frac{15}{4} r = 2.3775$ *feet = altitude of column of air, pressure of which = resistance to a spherical surface at a velocity of 16 feet.*

To Compute when Pressure of Air in rear of a Projectile is Inferior to Pressure due to its Velocity.

Assume height of barometer = 2.5 feet, and weight of atmosphere = 14.7 lbs.

Weight of cube inch of mercury $= \frac{14.7}{30} = .49$ lbs., and weight of cube inch of air = .000 043 57 lbs.; hence, $.49 \div .000\,043\,57 = 11\,246$, which $\times$ 2.5 feet = 28 115 feet.

Then $\sqrt{16.08} : \sqrt{28\,115} :: 32.16 : x$, and $x = \frac{32.16 \times \sqrt{28\,115}}{\sqrt{16}} = 1341.6$ *feet.*

To Compute Velocity with which a Plane Surface must be projected to generate a Resistance just equal to Pressure of Atmosphere upon it.

By table, resistance on a circle with an area of .222 sq. foot $(2 \div 9) = .051$ oz. at a velocity of 3 feet per second. Hence $3^2 : 1^2 :: .051 : .0056$ *oz. at a velocity of 1 foot*, and $1 \times 144 \times 14.7 \times 16 \times \overline{2 \div 9} = 7526.4$ *oz.* Hence, $\sqrt{.0056} : \sqrt{7526.4} :: 1 : 1160$ feet.

To Compute Velocity lost by a Projectile.

If a body is projected with any velocity in a medium of same density with itself, and it describes a space = 3 of its diameters,

$$\text{Then } x = 3\,d, \text{ and } b = \frac{3\,n}{8\,N\,d} = \frac{3}{8\,d}.$$

Hence, $b\,x = \frac{9}{8}$, and $\frac{c^{b\,x} - 1}{c^{b\,x}} = \frac{2.08}{3.08}$ = *velocity lost nearly .66 of projectile velocity.*

c = base of Nap. system of log.; hence $c^{b\,x}$ = number corresponding to Nap. log. $b\,x$. Hence, if $b\,x \times .4343$, result = com. log. of $c^{b\,x}$.

$b\,x = \frac{9}{8} = 1.125$, which $\times .4343 = .488\,587\,5$, and number to this com. log = 3.0803.

Hence, velocity lost $= \frac{3.0803 - 1}{3.0803} = \frac{2.08}{3.08}$.

ILLUSTRATION.—If an iron ball 2 ins. diam. were projected with a velocity of 1200 feet per second, what would be velocity lost after moving through 500 feet of space?

$$d = \frac{2}{12} = \frac{1}{6}, \quad x = 500, \quad N = 7\tfrac{1}{3}, \quad \text{and } n = .0012.$$

Hence, $b\,x = \frac{3\,n\,x}{8\,N\,d} = \frac{3 \times 12 \times 500 \times 3 \times 6}{8 \times 22 \times 10\,000} = \frac{81}{440}$, and $v = \frac{1200}{c^{\frac{81}{440}}} = 998$ *feet per second*, having lost 202 feet, or nearly $\frac{1}{6}$ of its initial velocity.

$\frac{12}{10\,000} = .0012$, $\frac{3}{22}$ and $\frac{6}{\cdot} = \frac{22}{3}$ and $\frac{1}{6}$ inverted, because N and n are in denominator.

To Compute Time and Velocity.

$$\frac{1}{b}\left(\frac{1}{v} - \frac{1}{a}\right) = time, \quad \frac{3\,n}{8\,N\,d} = b, \text{ and } \frac{a}{c^{b\,x}} = v.$$

ILLUSTRATION.—If an iron ball 2 ins. in diameter were projected in air with a velocity of 1200 feet per second, in what time would it pass over 1500 feet, and what its velocity at end of that time?

$b = \frac{3 \times 12 \times 3 \times 6}{8 \times 22 \times 10\,000} = \frac{1}{2716}$, and $b\,x = \frac{1500}{2716}$; hence $\frac{1}{b} = \frac{2716}{1}$; $\frac{1}{a} = \frac{1}{1200}$ and

$\frac{1}{v} = \frac{c^{b\,x}}{a} = \frac{1.7372}{1200} = \frac{1}{690}$ nearly. $\therefore v = 690$ and $t = 2716 \times \left(\frac{1}{690} - \frac{1}{1200}\right) = 1.67$

NAVAL ARCHITECTURE.

sults of Experiments upon Form of Vessels.

(*Wm. Bland.*)

ıbical Models. *Head Resistance.*—Increases directly with area surface. *Weight Resistance.*—Increases directly as weight.

essels' Models. *Lateral Resistance.*—About one twelfth of h of body immersed, varying with speed.

der of Superiority of Amidship Section.—Rectangle, Semicircular, se, and Triangle.

ntre of lateral resistance moves forward as model progresses.

ntre of gravity has no influence upon centre of lateral resistance.

Relative Speeds.

ıgth.—Increased length gives increased speed or less resistance.

oth of Flotation.—Less depth of immersion of a vessel, less the resistance.

ıidship Section.—Curved sections give higher speed than angled.

'es.—Slight horizontal curves present less resistance than right lines. ed sides with one fourth more beam give equal speeds with straight of less beam. *Keel.*—Length of keel has greater effect than depth. .—Parallel-sided after bodies give greater speed than taper-sided.

Form of Bow.	Order of Speed.
'es triangle, sides slightly convex	1
" " right lines	2
" " slightly concave at entrance and running convex	3

ierical equilateral triangle compared to *Equilateral triangle,* speed is to 12. *Equilateral triangle,* with its isosceles sides bevelled off at an of 45°, compared to bow with vertical sides, is as 5 to 4.

ıen bow has an angle of 14° with plane of keel, compared with one of ; speed is greater.

Bodies Inclined Upwards from Amidship Section.

Model with bow inclined from ⊠, has less resistance than model withny inclination.

Model with stern inclined from ⊠, has less resistance than model withny inclination.

ıdel 1 had less resistance than model 2. Model with both bow and inclined from ⊠, has less resistance than either 1 or 2.

Stability.

ults of Experiments upon Stability of Rectangular locks of Wood of Uniform Length and Depth, but f Different Breadths. (*Wm. Bland.*)

Length 15, *Depth* 2, *and Depression* 1 *inch.*

idth.	Weight.	Ratio of Stability. As Observed.	With like Weights.	By Squares of Breadth.	By Cubes of Breadth.
's.	Oz.				
	24	1	1	1	1
	35	2.5	2.4	2.25	3.375
	45	7	3.7	4	8
	55	11	4.8	6.25	15.625

Hence it appears that rectangular and homogeneous bodies of a ... length, depth, weight, and immersion in a fluid, but of different breadth, ... stability for uniform depressions at their sides (heeling) nearly *as s... of their breadth;* and that, when weights are directly as their brea... their stability under like circumstances is nearly *as cubes of their bread...*

With equal lengths, ratio of stability is at its limit of rapid increase ... width is one third of length, being nearly in cube ratio; afterwards i... proaches to arithmetic ratio.

Results of Experiments upon Stability and Spee... Models having Amidship Sections of different Fo... but Uniform Length, Breadth, and Weights. (W. B...

Immersion different, depending upon Form of Section.

FORM OF IMMERSED SECTION.	Stability.	S
Half-depth triangle, other half rectangle	12	
Rectangle	14	
Right-angled triangle*	7	
Semicircle	9	

* Draught of water or immersion double that of rectangle.

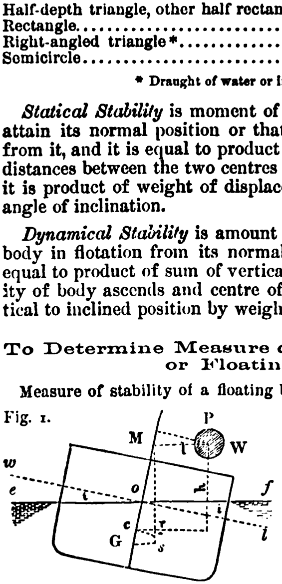
Statical Stability is moment of force which a body in flotation ex... attain its normal position or that of equilibrium, it having been de... from it, and it is equal to product of weight of fluid displaced and hori... distances between the two centres of gravity of body and of displacem... it is product of weight of displacement, height of *Meta-centre*, and S... angle of inclination.

Dynamical Stability is amount of mechanical work necessary to de... body in flotation from its normal position or that of equilibrium, an... equal to product of sum of vertical distances through which centre of ... ity of body ascends and centre of buoyancy descends, in moving from ... tical to inclined position by weight of body or displacement.

To Determine Measure of Stability of Hull of a Ve... or Floating Body.—Fig. 1.

Measure of stability of a floating body depends essentially upon horizont... tance, G s, of *meta-centre* of body from ... of gravity of body; and it is product of ... of the water, or resistance to displacem... it, acting upward, and distance of G s, o... G s. If distance, c M, represented by ... angle of rolling, c M r, by M°, measure o... bility, or S is determined by P r, sin. M°... and this is therefore greater, the great... weight of body, the greater distance of ... *centre* from centre of gravity of body, an... greater the angle of inclination of this ... c M r.

Fig. 1.



Assume figure to represent transverse section of hull of a vessel, G cent... gravity of hull, *w l* water-line, and *c* centre of buoyancy or of displacement ... ...rsed hull in position of equilibrium. Conceive vessel to be heeled or in... so that *e f* becomes water-line, and *s* centre of buoyancy; produce *s* M ... is *meta-centre* of hull of vessel.

... *meta-centre* depends upon position of centre of buoyancy, for it is that point ... drawn from centre intersects a line passing through centre of gravity of hull of ... to plane of keel.

...*tre* may be the same, or it may differ slightly for different angles of heeling. ... to ascertain position of meta-centre should be greatest which, under ordin... ...bable occurrence; in different vessels this angle ranges from 20° to 60°.

...re centre of gravity, equilibrium is Stable; if it coincides with it, equili... ...s below it, equilibrium is Unstable.

ırative Stability of different hulls of vessels is proportionate to the distance 'or same angles of heeling, or of distance G *s*. Oscillations of hull of a ves- be resolved into a rolling about its longitudinal axis, pitching about its 'se axis, and vertical pitching, consisting in rising and sinking below and ›sition of equilibrium.

ısverse section of hull of a vessel is such that, when vessel heels, level of ıf gravity is not altered, then its rolling will be about a permanent longi- ıxis traversing its centre of gravity, and it will not be accompanied by any oscillations or pitchings, and moment of its *inertia* will be constant while But if, when hull heels, level of its centre of gravity is altered, then axis hich it rolls becomes an instantaneous one, and moment of its *inertia* will it rolls; and rolling must then necessarily be accompanied by vertical os- s.

›scillations tend to strain a vessel and her spars, and it is desirable, therefore, ısverse section of hull should be such that centre of its gravity should not it rolls, a condition which is always secured if all water-lines, as *w l* and *e f*, ents to a common sphere described about G; or, in other words, if point of ersections, *o*, with vertical plane of keel, is always equidistant from centre ·y of hull.

To Compute Statical Stability.

sin. M = S. D *representing displacement*, M *angle of inclination, and* S

'RATION I.—Assume a ship weighing 6000 tons is heeled to an angle of 9°, *c* M = 3 feet,

Sin. 9° = .1564. Then 6000 × 3 × .1564 = 2815.2 *foot-tons.*

eight of a floating body is 5515 lbs., distance between its centre of gravity *ı-centre* is 11.32 feet, and angle M = 20°.

: = .342 02. Hence 5515 × 11.32 × 342 02 = 21 352.24 *foot-lbs.*

Statical Surface Stability.

ent of Statical surface stability at any angle is *c z* D. Assuming ›f gravity of vessel coincided with *c*; coefficient of a vessel's stability angle of heel is expressed when the displacement is multiplied by . height of the *meta-centre* for given angle of heel above centre of , or D *c* M.

oximately. RULE.—Divide moment of inertia of plane of flotation ight position, relatively to middle line by volume of displacement; ›tient multiplied by sine of angle of heel will give result.

'oot of Length of Vessel, $\frac{2}{3}$ (B³ sin. M). B *representing half breadth.*

Dynamical Surface Stability.

ent of Dynamical surface stability is expressed by product of weight ·l or displacement and depression of centre of buoyancy during the ion, that is, for angle M.

'o Compute Dynamical Stability of a Vessel.

oximately. RULE.—Multiply displacement by height of *meta-centre* entre of gravity, and product by versed sine of angle of heel.

ultiply statical stability for given angle by tangent of .5 angle of heel.

›mpute Elements of Stability of a Floating Body.

$= s$, $\frac{c}{\text{sin. M}} = r$, $\frac{s}{\text{sin. M}} = g$, and sin. M $r = c$. A *representing area of d section;* A' *section immersed by careening of body, as f o l; s horizontal , c r, between centres of buoyancy; a horizontal distance between centres of i i, of areas immersed and emerged by careening; g distance,* c M, *between f buoyancy or of water displaced and meta-centre; r* distance, G M, *between f gravity and meta-centre; c horizontal distance,* G s, *between* centre *of grav- ›f line of displacement of it when careened; e vertical* distance *between* centres *'y and buoyancy, all in feet; and* M *angle of careening.*

NOTE.—When centre of gravity, G, is below that of displacement, c, then e is +; when it is above c it is —; and when it coincides with c it is o; or e is — when $\frac{S}{P} < s$; and a body will roll over when e sin. M = or $> s$.

Assumed elements of figure illustrated are $A = 86$, $A' = 21.5$, $b = 21.5$, and $c = 5$.

The deduced are $s = 3.7$, $c = 3.87$, $g = 10.82$, $a = 14.9$, and $r = 11.32$. *b representing breadth at water-line or beam in feet, and P weight or displacement in lbs. or tons.*

Then $s = \frac{21.5}{86} \times 14.9 = 3.7$ *feet*, $r = \frac{3.87}{.34202} = 11.32$ *feet*, $e = r - g$, $g = \frac{3.7}{.342}$ $= 10.82$ *feet*, $c = .34202 \times 11.32 = 3.87$ *feet.*

Of Hull of a Vessel. $\left(\frac{b^3}{10.7 \text{ to } 13^* A} \pm e\right) P, \sin. M = S$; $\quad d \cos. .5 M = d'$

$\frac{b^3}{10.7 \text{ to } 13\,(11.93)\,A} = g$, $\quad \frac{1}{\sin. M}\left(\frac{S}{P} - s\right) = \pm e$; $\quad P\left(\frac{b\,a}{A} + \overline{e \sin. M}\right) = S$; or

$P\,(s \pm \overline{e \sin. M}) = S$. *d representing depth of centre of gravity of displacement under water in equilibrium, and d′ depth when out of equilibrium, both in feet.*

ILLUSTRATION 1.—Displacement of a vessel is 10 000 000 lbs.; breadth of beam feet; area of immersed section, 800 sq. feet; vertical distance from centre of gravity of hull up to centre of buoyancy or displacement, 1.9 feet, and horizontal distance a between centres of gravity of areas immersed and emerged, when careened to an angle of 9° 10′ = 33.4 feet, immersed area being 50 sq. feet.

Sin. 9° 10′ = .1593. Then $s = \frac{50}{800} \times 33.4 = 2.0875$ *feet*, $800 \times 2.0875 = 50 \times 33.4$

$r = \frac{2.39}{.1593} = 15$ *feet.* $\quad g = \frac{50^3}{11.93 \times 800} = 13.1$ *feet*, $\quad S = \left(\frac{50^3}{11.93 \times 800}\right) + 1.9$

$10\,000\,000 \times .1593 = 23\,905\,396$ *lbs.*, and $e = \frac{1}{.1593}\left(\frac{23\,905\,396}{10\,000\,000} - 2.0875\right) = 1.9$ *feet.*

2.—Assume a ship having a displacement of 5000 tons, and a height of meta-centre of 3.25 feet, to be careened to 6° 12′. What is her statical stability?

Sin. 6° 12′ = .1079. Then $5000 \times 3.25 \times .1079 = 1753.37$ *foot-tons.*

3.—Assume a weight, W, of 50 tons to be placed upon her spar deck, having a common centre of gravity of 15 feet above her load-line,

Then $5000 \times 3.25 - \overline{50 + 15} \times .1079 = 1747.36$ *foot-tons.*

4.—Assume 100 tons of water ballast to be admitted to her tanks at a common centre of gravity of 15 feet below her load-line,

Then $5000 \times 3.25 + \overline{100 \times 15} \times .1079 = 1915.22$ *foot-tons.*

5.—Assume her masts, weighing 6 tons, to be cut down 20 feet,

Then $\frac{10 \times 20}{5000} = \frac{2}{50}$ foot = *fall of centre of gravity*, and $5000 \times \left(3.25 + \frac{2}{50}\right) \times .1079$ $= 1774.95$ *tons.*

To Compute Elements of Power, etc., required to Careen a Body or Vessel.

Sin. M $(h - \overline{n \sin. M}) + \overline{n \sec. M} - s = l$. $\quad \frac{b^3}{10.7 \text{ to } 13^* A} \sqrt[3]{\frac{P}{64.125\, l\, A}} = s$

$W\,l\,r = P\,c$, and $W\,l = S$. *W representing weight or power exerted or at which weight or power acts to careen body, taken from centre of gravity ment perpendicular to careening force, h vertical height from centre of gr placement to centre of weight or power to careen body when it is in e n horizontal distance from centre of vessel to centre of weight or power.* vessel, *m* meta-centre, and S as in preceding case, all in feet.

* Unit for section of a parallelogram is 10.7; of a semicircle 12, and of a triangle

ILLUSTRATION.—A weight is placed upon deck of a vessel at a mean height of 3.87 m centre line of hull; height at which it is placed is 11.32, and other eles in first case given.

20° = .342. Then $h = 11.32$, $s = 3.87$, and $l = .342\ (11.3 - \overline{3.87 \times .342}) + \overline{1.0642} - 3.7 = .342 \times 10 + 4.12 - 3.7 = 3.84$ *feet.*

me W = 5515. Then 5515 × 3.84 = 21 187.6 *foot-lbs.*

(w cos. M + h sin. M) = S. *w representing distance of weight from centre of and h height of w above water-line, both in feet.*

ILLUSTRATION.—If a weight of 30 tons placed at 20 feet from centre of hull or o feet above water-line, careens it to an angle of 2° 9′, what is its stability?

cos. 2° 9′ = .9993; sin. 2° 9′ = .0375.

30 (20 × .9993 + 10 × .0375) = 30 × 20.361 = 610.83 *foot-tons.*

;om and Immersed Surface of Hull of Vessels.

o Compute Bottom and Side Surface of Hull.

om and Side. RULE.—Multiply length of curve of amidship section, from top of tonnage or main deck beams upon one side to same point other (omitting width of keel), by mean of lengths of keel and beperpendiculars in feet, multiply product by .85 or .9 (according to the ty of vessel), and product will give surface required in sq. feet.

IPLE.—Lengths of a steamer are as follows: keel 201 feet, and between perilars 210 feet, curved surface of amidship section 76 feet; what is surface?

cient .87. $\overline{210 + 201} \div 2 = 205.5$, and 76 × 205.5 × .87 = 13 587 *sq. feet.*

.—Exact surface as measured was 13 650 sq. feet.

om Surface. RULE.—Multiply length of hull at load-line by its ı, and this product by depth of immersion (omitting the depth of n feet; and this product multiplied by from .07 to .08 (according to ;y of vessel) will give surface required in sq. feet.

IPLE.—Length upon load-line of a vessel is 310 feet, beam 40 feet, depth of oot, and draught of water 20 feet; what is bottom or wet surface?

Coefficient assumed .073. $310 \times 40 \times \overline{20 - 1} \times .073 = 17\ 199$ *sq. feet.*

› Compute Resistance to Wet Surface of Hull.

² = R. C *representing a coefficient of resistance, a area of wet surface in sq. d v velocity of hull in feet per second.*

lues of C, {.007, clean copper. {.01, smooth paint. | .014, iron plate. .019, iron plate, moderately foul.

r required to propel one sq. foot of immersed amidship section at ⊠ is .073 smooth wet surface.

To Compute Elements of a Vessel.

Displacement and its Centre of Gravity.

lacement of a vessel is volume of her body below water-line.

're of Gravity, or Centre of Buoyancy or Displacement, is centre of y of water displaced by hull of vessel.

Displacement. RULE.—Divide vessel, on half breadth plan, into a r of equidistant sections, as one, two, or more frames, commencing and running each side of it. Add together lengths of these lines in ore and aft bodies, except first and last, by Simpson's rule for areas age 344); multiply sum of products by one third distance between is, and product will give area of water-line between fore and aft-sections.

ı compute areas contained in sections forward and aft of sections taken, in-g stern and rudder-post, rudder and stem, and add sum to area of body-sec-lready ascertained.*

* *To Compute Area of a Water-line,* see Mensuration of Surfaces, page 344.

Compute area of remaining water-lines in like manner. Tabulate re multiply them by Simpson's rule in like manner as for a water-line, an consecutive number of water-lines, and sum of products between wate product will give volume between load and lower water-line.

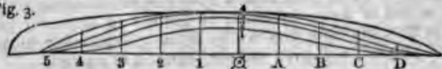
Add area of lower water-line to area of upper surface of keel; multipl by distance between them, and product will give volume; then compute tained in sections forward and aft of sections taken as before directed.

If keel is not parallel to lower water-line, take average of distance betw

Compute volume of keel, rudder-post and rudder below water-line; add already ascertained; multiply product by two, for full breadth, and p give volume required in cube feet, all dimensions being taken in feet.

Fig. 2.

Fig. 3.



EXAMPL a vessel length by extreme load-line inches i Figs. 2 a

Distan sections, of simpl example, at 10 fe frames a ins. apart, and two or more included in a section. Water-lines 2 feet ap

1st Water-line.

4	5			=	5
3	7.7	×	4	=	30.8
2	9.5	×	2	=	19
1	9.9	×	4	=	39.6
0	10	×	2	=	20
A	9.6	×	4	=	38.4
B	7.8	×	2	=	15.6
C	6.8	×	4	=	27.2
D	4			=	4
					199.6
	10 ÷ 3			=	$3\frac{1}{3}$
					665.3
Abaft section 4, rudder and post					25
Forward section D and stem					20.7
					711

2d Water-line.

4	2.7			=	2.7
3	6.9	×	4	=	27.6
2	8.7	×	2	=	17.4
1	9.5	×	4	=	38
0	9.6	×	2	=	19.2
A	9	×	4	=	36
B	7	×	2	=	14
C	5	×	4	=	20
D	2			=	2
					176.9
	10 ÷ 3			=	$3\frac{1}{3}$
					589.7
Abaft section 4, rudder and post					13.2
Forward section D and stem					9.1
					612

3d Water

4	1.5	
3	5	×
2	6.6	×
1	8.7	×
0	8.9	×
A	7.6	×
B	7	×
C	3	×
D	1.2	
	10 ÷	
Abaft section 4 der and post		
Forward secti and stern...		

4th Water-line.

4	.7			=	.7
3	2	×	4	=	8
2	4.3	×	2	=	8.6
1	6.5	×	4	=	26
0	6.8	×	2	=	13.6
A	5	×	4	=	20
B	3.6	×	2	=	7.2
C	.9	×	4	=	3.6
D	.3			=	.3
					88
	10 ÷ 3			=	$3\frac{1}{3}$
					293.3
ection 4, rud- d post					3.2
section D m.........					.8
					297.3

Keel.

Half breadth = .25 × length of 98 feet:
Rudder-post and rudder...............

Results.

1st water-line	711		711	
2d "	612	× 4 =	2448	× 1 = 2
3d "	495.4	× 2 =	990.8	× 2 = 1
4th "	297.3	× 4 =	1189.2	× 3 = 3
Keel	24.8		24.8	× 4 =
			5363.8	8
			2	
			3)10727.6	

Displacement, 3575.9 × 2 =

To Compute Centre of Gravity of Displacement.

Rule.—Divide sum of products obtained as above, by consecutive water-lines, by sum of products obtained in column of products by Simpson's multipliers, and quotient, multiplied by distance between water-lines, will give depth of centre below load water-line.

Illustration i. 8096.4, from above, $\div 5363.8 = 1.5$, which $\times 2 = 3$ feet.

$$\frac{n}{2\left(2-\frac{D}{a\,n}\right)} = d.$$ *n representing draught of water exclusive of any drag of keel, a area of immersed surface of hull in sq. feet, and D displacement in cube feet.*

—Assume draught of water 8 feet, displacement 7152 cube feet, and area of immersed surface of hull 1100 sq. feet.

$$\text{Then } \frac{8}{2\left(2-\frac{7152}{1100\times 8}\right)} = \frac{8}{2\times 1.187} = 3.37 \textit{ feet.}$$

To Compute Displacement Approximately.

Coefficient of Displacement of a vessel is ratio that volume of displacement bears to parallelopipedon circumscribing immersed body.

$\frac{V}{L\,B\,D} = C.$ V *representing volume of displacement in cube feet,* L *length at immersed water-line,* B *extreme breadth, and* D *draught in depth of immersion, both in feet.*

Coefficient of Area of Amidship Section in Plane of a Water-line is ratio which their areas bear to that of circumscribing rectangle.

L representing length of water-line, and D *distance between water-lines, both in feet.*

Coefficients. (*By S. M. Pook, Constructor U. S. Navy.*)

Rule.—Multiply length of vessel at load-line by breadth, and product by depth (from load-line to under side of garboard-strake) in feet, and this product by coefficient for vessel as follows: divide by 35 for salt water, 36 fresh water, and quotient will give displacement in tons.

Amidship sections range from .7 to .9 of their circumscribing square, and mean horizontal lines from .55 to .75 of their respective parallelograms. Hence, ranges vessels of least capacity to greatest are $.7 \times .55 = .385$, and $.9 \times .75 = .675$.

Merchant ship, very full	.6 to .7	Merchant steamer, medium	.52 to .54
" " medium	.58 to .62	Clipper	.5 to .54
River steamer, stern-wheel	.6 to .65	Schooner, medium	.48 to .52
Ship of the line	.5 to .6	River steamer, tug-boat, sharp	.45 to .5
Naval steamer, first class	.5 to .6	" " medium	.45 to .5
"	.52 to .58	" " sharp	.42 to .45
Merchant steamer, sharp	.54 to .58	Schooner, sharp	.46 to .5
Sharp clipper	.52 to .56	Yachts, sharp	.4 to .45
Brigs, barks, etc.	.52 to .56	" very sharp	.3 to .4
River steamer, tug-boat, med'm	.52 to .56	River steamers, very sharp	.36 to .42

The steam launch *Miranda*, when making 16.2 knots per hour, with a displacement of 58 tons, her coefficient was 3.

To Compute Chan[illegible] Trim.

$\frac{W\,d}{D} \times \frac{L}{m} = d'.$ D *representing displacem[illegible] draught in tons,* L *length* [illegible] *same line in feet, and m longitudinal meta-* [illegible]

Illustration.—"*Warrior*," at draught of [illegible] feet, $m = 475$ feet, $D = 8625$ tons. If, then, a weight of 20 t[illegible] and aft 100 feet,

$$\frac{20\times 100}{8625} \times \frac{380}{475} = .1856.$$

Illustration.—*Vertical Plane at ⊠ and Horizontal at Load-line.*

Elements of a Steam Frigate.	Weight.	Horizontal. Distances. Forward.	Distances. Abaft.	Moments. Forward.	Moments. Abaft.	Vertical. Distances. Above.	Distances. Below.	Moments. Above.	Moments. Below.
	Tons.	Feet.	Feet.			Feet.	Feet.		
Hull, bunkers, and cement in bottom	1075	1.6	—	1 720	—	—	1	—	1075
Engines, boilers, water, and stores	470	—	29	—	13 630	—	6.3	—	3011
Coal	252	16	—	4 032	—	—	4	—	1008
Battery and ammunition	131.5	62	—	8 153	—	2	—	263	—
Masts, spars, sails, and rigging	24	27	—	648	—	31	—	744	—
Anchors and cables	25	40	—	1 000	—	—	6	—	150
Boats	3.25	—	48	—	156	16	—	52	—
Water and ship's stores	22	40	—	880	—	—	3	—	66
Provisions and galley	30	1.2	—	360	—	5	—	150	—
Crew and effects	30	17	—	510	—	7	—	210	—
Officers' and mess stores	7.25	—	40	—	290	—	8	—	58
Total	2070			17 303	14 076			1419	5368

Moments forward ⊠, 17 303 — moments abaft, 14 076 = 3227 ÷ 2070 tons (*weight*) = 1.56 *feet = distance of centre forward of* ⊠.

Moments above load-line, 5368 — moments below, 1419 = 3949 ÷ 2070 tons (*weight*) = 1.91 *feet = distance of centre below load-line.*

NOTE.—Rule, in Strength of Materials, to compute common centre of gravity, page 819, would apply in this case.

To Compute Centre of Gravity of Bottom Plating of a Vessel.

Longitudinal.

RULE.—Measure half girths of plating at equidistant sections, at two or more frames. Multiply these in accordance with Simpson's rule for areas and add products together.

...ly each of these products in their order, by number ...

... number of intervals of section ...

Divide difference of these moments by sum of products of half girths, previously obtained.

Multiply product by common distance between sections, and result will give distance of centre of gravity from ⊠ in a horizontal plane.

To Compute Depth of Centre of Gravity or Buoyancy Below Meta-Centre.

$\frac{S}{D \sin. M} = d.$ S *representing statical stability*, D *displacement in tons, and* sin. M *sine of angle of heel.*

ILLUSTRATION.—Elements of Fig. 2, page 634, are, statical stability at angle of 5.44°, 90 tons, and displacement 204.33 tons.

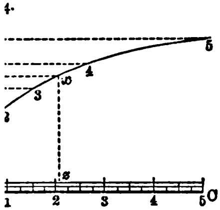
ıpute Centre of Gravity or Buoyancy Approximately.

ıf *mean draught of hull*, using larger coefficient for full-bodied vessels.

To Delineate Curve of Displacement.

rve is for purpose of ascertaining volume of water or tons weight, by immersed hull of a vessel at any given or required draught; or ıuired to depress a hull to any given or required draught. From computation for displacement of vessel, proceed as follows, Fig. 4:

4.



On a vertical scale of feet and ins., as A B, set off depths of keel and water-lines, draw ordinates thereto representing displacement of keel, and at each water-line, in tons.

Through points 1, 2, 3, 4, and 5 delineate curve A 5, which will represent displacement at any given or required draught.

Draw a horizontal scale corresponding to weight due to displacement at ıs A C, and subdivide it into tons and decimals thereof, and a verlet fall from any point, as x, at a given draught, will indicate displacement at depth, on scale A C, and, contrariwise, a line raised point, as z, on A C will give draught at that weight.

TION.—Displacement of hull (page 654) at load-line $= 7151.8$ cube feet, ; for salt water $= 204.3$ tons, hence A C represents tons, and is to be subordingly.

aunching draught to have been 4 feet, then a vertical let fall from 4 will ıight of hull in tons on A C.

Coefficients. (By C. Mackrow, M. I. N. A.)

ION OF VESSEL.	Length.	Breadth.	Mean Draught.	Displacement.	Coefficient. Amidship Section.	Water-lines.
....	225	45	15	.715	.932	.755
	325	59	24.75	.64	.81	.71
ers...........	350	35	21	.687	.85	.84
	385	42	22	.659	.88	.8
	368.27	42.5	18.71	.516	.812	.635
small.........	220	27	8	.702	.912	.742
	90	15	4	.637	.914	.704
....	125	23	8	.536	.87	.616
	160	31.3	12	.466	.745	.603
s.............	350	49.12	23.5	.47	.674	.7
	340.5	46.13	15.75	.4	.68	.582
l Steamers....	337.3	50.28	22.75	.483	.787	.614
	270	42	19	.497	.792	.628
ers, R. N........	300	40.27	14	.414	.711	.711

Curve of Weight.

npute Number of Tons required to Dep el One Inch at any Draught of Water P Water-line.

-Divide area of plane by 12, and again by 35 or 36, as or salt or fresh water.

.—Area of load water-line of a vessel is 1422 sq. feet; what is inch in salt water?

$1422 \div 12 = 118.5$, which $\div 35 = 3.38$ tons.

To Compute Common Centre of Gravity of Hull, Ar- mament, Engine, Boilers, etc., of a Vessel.

RULE.—Compute moments of the several weights, relatively to assig[illegible] horizontal and vertical planes, by multiplying weight of each part by [illegible] horizontal and vertical distance from these planes.

Add together these moments, according to their position forward or aft, [illegible] above or below these planes, and difference between these sums will give p[illegible] sition forward or aft, above or below, according to which are greatest.

Divide results thus ascertained by total weight of vessel, and product [illegible] give horizontal and vertical distances of centre of gravity from these pla[illegible]

It is customary to assume vertical plane at ⊠, and horizontal plane [illegible] load-line.

NOTE.—In following illustration, in order to simplify computation in table, [illegible] mon centre of gravity of hull, machinery, etc., is taken, instead of centres of in[illegible] vidual parts, as engine, boiler, propeller, etc.

ILLUSTRATION.—Assume half-girths as in following table, and distance betw[illegible] sections 10 feet.

FORWARD.					
Section.	Half-Girths.	Multipliers.	Product.	Multipliers.	Moments.
No.	Feet.				
⊠ ...	25	1	25	—	—
A....	23	4	92	1	92
B....	21	2	42	2	84
C....	19	4	76	3	228
D....	17	2	34	4	136
E....	15	1	15	5	75
					615

ABAFT.					
Section.	Half-Girths.	Multipliers.	Product.	Multipliers.	M[illegible]
No.	Feet.				
1 ...	23	4	92	1	[illegible]
2 ...	20	2	40	2	[illegible]
3 ...	18	4	72	3	[illegible]
4 ...	16	2	32	4	[illegible]
5 ...	14	1	14	5	[illegible]
			534		[illegible]

Moments forward, 615 — moments abaft, 586 = 29 ÷ sum of product 534 = [illegible] which × 10 feet = .54 *feet forward* of ⊠.

Centre of Lateral Resistance.

Centre of Lateral Resistance is centre of resistance of water, and as its p[illegible] sition is changed with velocity of vessel, it is variable. It is generally ta[illegible] at centre of immersed vertical and longitudinal plane of vessel when o[illegible] an even keel.

If vessel is constructed with a drag to her keel, the centre will be m[illegible] proportionately abaft of longitudinal centre.

Yacht *America* had a drag to her keel of 2 feet, and centre of later[illegible] sistance of her hull was 8.08 feet abaft of centre of her length on load-li[illegible]

Centre of Effort.

Centre of Effort is centre of pressure of wind upon sails of a vessel [illegible] vertical and longitudinal plane. Its position varies with area and le[illegible] of sails that may be spread, and it is usually taken and determined by [illegible] ordinary standing sails, such as can be carried with propriety in a mod[illegible] fresh breeze.

In computing this position, the yards are assumed to be braced dir[illegible] and aft and the sails flat.

NOTE.—Centre of effort of sails, to produce greatest propelling effect, m[illegible] with capacity of vessel at her load-line, compared with fullness of her body at its extremities. Thus, a vessel with a full load-line and sharp [illegible] below, will sustain a higher centre of effort than one of dissimilar con[illegible] struction.

To Compute Location of Centre of Effort.

ꞮULE.—Multiply area of each sail in square feet by height of its centre of vity above centre of lateral resistance in feet, divide sum of these prod- ı (moments) by total area of sails in square feet, and quotient will give ;ht of centre in feet.

Multiply area of each sail in square feet, centre of which is forward of ertical plane passing through centre of lateral resistance, by direct dis- e of its centre from that plane in feet, and add products together.

Proceed in like manner for sails that are abaft of this plane, add their lucts together, and centre of effort will be on that side which has greatest nent of sail.

KAMPLE.—Assume elements of yacht *America* as rigged when in U. S. Service.

SAIL.	Area.	Height of Cent. of Gravity of Sails.	Vertical Moments.	Distance of Centre of Gravity of Sails. Foreward.	Abaft.	Moments. Foreward.	Abaft.
	Sq. Feet.	Feet.					
ng Jib..........	656	28	18 368	52	—	34 112	—
....	1087	26	28 262	32	—	34 784	—
sail............	1455	34	49 470	—	3	—	4 365
nsail...........	2185	35	76 475	—	40	—	87 400
	5383		172 575			68 896	91 765

$\frac{\text{ertical moments } 172\,575}{\text{rea of sails ..... } 5\,383} = 32.06 =$ *height of centre above centre of lateral re- ·nce.*

oments $\left\{ \frac{91\,765 \sim 68\,896}{5383} \right. = 4.25 =$ *distance of centre abaft centre of lateral re- ınce.*

lative Positions of Centre of Effort and of Lateral Resistance.

quare Rig. $\frac{L\,(.75\,d' + d'')}{10\,(d' + d'')} = E.$ *Fore and Aft Rig.* $\frac{L}{10\,(d' + d'')} = E,$

$\frac{4}{5}\frac{A}{d} = E'$. L *representing length of load-line*, d *distance of centre of buoyancy essel below it*, d′ *distance of centre of lateral resistance abaft centre of it*, d″ *dis- e of centre of buoyancy before centre of it*, E *distance of centre of effort before re of lateral resistance, and* E′ *distance of centre of effort above centre of lateral stance.*

Meta-Centre.

Ieta-centre of a vessel's hull is determined by location of centre of grav- or buoyancy of immersed bottom of hull, for it is that point in transverse ion of hull, where a vertical line raised from its centre of gravity or yancy intersects a line passing through centre of gravity of hull, as . 1, page 650.

To Compute Height of Meta-Centre.

By Moment of Inertia. $\frac{I}{D} = M.$ I *representing moment of inertia of area water-line or plane of flotation, and* D *volume of displacement ir*

ꞮOTE.—*Moment of Inertia* of an area is sum of products of ea a, by square of its distance from axis, about which moment nputed.

To Ascertain Moment of Inertia approx

Rectangle $= C\,L\,B^3$; $C = \frac{1}{12}$ when $L = 4\,B$; $C = \frac{3}{50}$ when L =

when L = 6 B. With very fine lines and great proportionate

nd B measured at load-line.

ILLUSTRATION.—Assume length of vessel 233 feet, breadth 43, draught 16, and displacement 2700 tons. Length = 5.65 beams; hence C is taken at $\frac{21}{400}$. Volume of displacement = 2700 × 35 = 92 500 cube feet.

Then $\frac{21 \times 233 \times 43^3}{400 \times 92\,500} = 10.51$. Exact height of moment was 10.44 *feet.*

By Ordinates. RULE.—Divide a half longitudinal section of load water-line by ordinates perpendicular to its length, of such a number that area between any two may be taken as a parallelogram. Multiply sum of cubes of ordinates by respective distances between them, and divide two thirds of product by volume of immersion, in cube feet.

ILLUSTRATION.—Take dimensions from Figs. 2 and 3, page 654.

	Length.	Cube.		Length.	Cube.	Cube.
4	5	125	A	9.6	885	51 460
3	7.7	456	B	7.8	475	2
2	9.5	857	C	6.8	314	3)102 920
1	9.9	970	D	4	64	
⊗	10	1000			5146 × 10	7151.8) 34 306.6 = 4.79

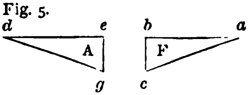
If there are more ordinates, their coefficients must be taken in like manner, 1—4—2—4—2—4—1.

For operation of this method, see Simpson's rule for areas, page 342.

Or, $\frac{2}{3}\int \frac{y^3\,dx}{D} = M.$ *y representing ordinates of half-breadth sections of load-line, d x increment of length of load-line section or differential of x, and D displacement of immersed section in cube feet.*

By Areas. $\dfrac{\frac{2}{3}(a^3 + 4\,b^3 + 2\,c^3 + 4\,d^3 + e^3)\frac{l}{3} + F + A}{D} = M.$ *a, b, c, d and e representing ordinates of 1st or load water-line, F area of irregular section between 1st frame and stem, and A area of like section between last frame and stern-post, both in sq. feet, D displacement, in cube feet, and l distance between frames or sections of water-line, as may be taken, in feet.*

Fig. 5.



To Ascertain Areas of F and A—Fig. 5.

$\frac{2}{3}\,a\,b \times b\,c^3 \div 4 = F$, and $\frac{2}{3}\,d\,e \times e\,g^3 \div 4 = A$

Elements of Capacity and Speed of Several Types of Steamers of R. N. (*W. H. White.*)

CLASSES.	Length.	Length to Breadth.	Displacement.	Speed.	IHP to Displacement.	Displacement [illegible]
IRON-CLADS.	Feet.		Tons.	Knots.		
Recent types.	300 to 330	5.25 to 5.75	7500 to 9 000	14 to 15	.9 to 1	16 [illegible]
do. twin sc.	280 to 320	4.5 to 5	6000 to 9 000	14 to 15	.7 to .9	15 [illegible]
UNARMORED.						
Swift cruisers	270 to 340	6.5 to 6.75	3000 to 5 500	15 to 16	1.3 to 1.5	20 [illegible]
Corvettes....	200 to 220	6	1800 to 2 000	12.75 to 13.25	1 to 1.2	13 [illegible]
[illegible]ips........	160	5	850 to 950	11	1 to 1.2	10 [illegible]
[illegible] vessels..	125 to 170	5.5 to 6.25	420 to 800	9.5 to 11	.8 to 1.4	7 [illegible]
[illegible]	80 to 90	3 to 3.25	200 to 250	8 to 9	.8 to 1.1	5 [illegible]
[illegible]	[illegible]0 500	9 to 11	7000 to 10 000	14 to 15	.5 to .6	[illegible]
[illegible]	[illegible]0 400	8 to 10	5000 to 7 000	13 to 14	.4 to .5	[illegible]
[illegible]	[illegible]	7.5 to 10	3000 to 6 000	11 to 15	.3 to .5	[illegible]
[illegible]	[illegible]	[illegible] to 9	1500 to 4 000	9 to 11	.2 to . [illegible]	[illegible]

ompute Power Required in a Steam Vessel, capacity of another Vessel being given.

essels of similar models. $\frac{v\,A}{a} = V$; $\frac{S^3\,V}{s^3} = V'$; $\frac{r\,V'}{r'} = C$; and $\frac{C}{2\,r'} = R$;

I' representing product of volumes of given and required cylinders and revo- in cube feet, a and A areas of immersed section of given and required n sq. feet at like revolutions and speed of given vessel, s and S speeds of given quired vessel at revolutions of given vessel, both in feet per minute, r and r' ions of given and required vessel per minute, and C product of volume of com- ylinder and revolutions for required vessel.

STRATION.—A steam vessel having an area of amidship section of 675 sq. feet, o cylinders of a combined capacity of 533.33 cube feet, and a speed of 10.5 per hour, with 15 revolutions of her engines. Required volume of steam rs, with a stroke of 10 feet, for a section of 700 feet and a speed of 13 knots .5 revolutions.

$33.33 \times 15 = 8000$ *cube feet,* $\frac{8000 \times 700}{675} = 8296.3$ *cube feet,* $\frac{13^3 \times 8296.3}{10.5^3} =$

cube feet, $\frac{15 \times 15\,745.2}{14.5} = 16\,288.1$ *cube feet,* and $\frac{16\,288.1}{2 \times 14.5} = 561.66$ *cube*

hich $\div$ 10 *stroke of piston,* 12 *for ins., and* $\times$ 1728 *ins. in a cube foot* $=$

$\frac{\times 1728}{\times 12} = 8087.9$ *sq. ins. area of each cylinder = diameter of* 101.5 *ins.*

roximate Rules to Compute Speed and IHP of Steam Vessels.

$= C$; $\sqrt[3]{\frac{C\,IHP}{D^{\frac{2}{3}}}} = V$; and $\frac{V^3\,D^{\frac{2}{3}}}{C} = IHP$. Or, $\sqrt[3]{\frac{C\,IHP}{A}} = V$; and $\frac{V^3\,A}{C} = IHP$.

resenting coefficient of vessel, A area of immersed amidship section in sq. feet, ity of vessel in knots per hour, and D displacement of vessel in tons.

:.—When there exists rig, an unusual surface in free board, deck-houses, etc., element that effects coefficient for class of vessel given, a corresponding ad- to, or decrease of, following units is to be made:

ge of Coefficients as deduced from observation is as follows:

SIDE-WHEEL.				C		PPOPELLER.				C	
SSEL.	A	D	V	$\frac{V^3\,A}{IHP}$	$\frac{V^3\,D^{\frac{2}{3}}}{IHP}$	VESSEL.	A	D	V	$\frac{V^3\,A}{IHP}$	$\frac{V^3\,D^{\frac{2}{3}}}{IHP}$
mboat.	Sq.F.	T's.	K'ts.			*Steamboat.*					
. lines	43	73	10	470	212	Medium lines..	45	—	12	—	500
"	150	465	13	570	219	" "		—	—	—	—
es........	136	300	19	540	200	Fine lines	150	—	15	—	530
imer.						*Steamer.*					
full lines*	675	3600	10	650	214	Medium full...	550	2532	9	194	570
—	—	—	—	—	—	" " *..	390	1475	10	180	470
est†.......	880	5233	15	650	211	—		3600	13	210	—
—	—	—	—	—	—	Torpedo boat..		97	20	170	500

* Full rigged. † Bark rigged.

efficients as Determined by Several Steamers of H. B M Service.

(C. Mackrow, M. I. N. A.)

h.	Length / Beam.	Area of Section at ⊗.	Displacement.	IHP	S
.		Sq. Feet.	Tons.		Ki
	6.53	236	775	782	1c
	5.89	377	1554	1070	1c
	7.33	814	5898	2084	11
	6.43	632	3057	2046	12
	6.52	1308	9487	3205	12.
	6.73	1198	9152	5971	13.
	7.33	778	5600	3945	14.
	6.73	1185	9071	6867	15.

Approximate Rule for Speed of Screw Propell

(*Molesworth.*)

$\frac{101\ V}{P} = N$; $\frac{P\ N}{101} = V$; $\frac{101\ V}{N} = P$; $\frac{88\ v}{P} = N$; $\frac{P\ N}{88} = v$; and $\frac{8}{}$

V and v representing velocities in knots and miles per hour, P *pitch of prop feet, and* N *number of revolutions per minute.*

This does not include slip, which ranges from 10 to 30 per cent.

Pitch of Screw Propeller.

Pitch ranges with area of circle described by diameter of screw to t amidship section.

Area of screw circle to amidship section $\doteq$ 1 to	6	5	4.5	4	3.5	3	2.5
Two Blades.							
Pitch to diameter of screw = 1 to	.8	1.02	1.11	1.2	1.27	1.31	1.4
Four Blades.	1.08	1.38	1.5	1.62	1.71	1.77	1.89

Length = .166 diameter.

Slip of Side-wheels.

Radial Blades. $\frac{2\,(A - c)}{A} = S$. *Feathering.* $\frac{1.5\,(A - c)}{A} = S$. A *repre length of arc of immersed circumference of blades,* c *length of chord of immers and* S *slip, all in feet.*

Area of Blades.

River Service. $\frac{.75\ IHP}{D} = A$. *Sea Service.* $\frac{IHP}{D} = A$. D *representing di of wheel in feet, and* A *area of each blade in square feet.*

Length of Blades. .7 in River service and .6 in Sea service.

Distances between Radial Blades. 2.25 in River service and 3 feet in Sea s *between Feathering blades,* 4 to 6 feet.

Proportion of Power Utilized in a Steam Vess

Side Wheel. $\frac{P - z}{.000\,002\,59\ d^3\ r^2} = C$. P *representing gross* IHP, *z effect by slip and oblique action of wheels, d diameter of wheels at centre o r revolutions per minute, and* C *coefficient for vessel.*

ILLUSTRATION.—IHP of engines of a side-wheel steamer is 1120; slip of and loss by oblique action, 33.37 per cent.; diameter of centre of effect of w 29.5 feet, and number of revolutions 13.5 per minute; what is coefficient, an power applied to propel vessel?

NOTE.—Slip of wheels from their centre of effect in this case is 15.37 pe and loss by oblique action 18 per cent. Hence, representing total power 100 — (18 + 15.37) = 66.63 per cent. of power applied to wheels.

As assumed power that operates upon wheels in this case is taken at 86 cent. of power exerted by engines, 86.12 × 33.37 = 28.74 per cent. for sum by wheels.

$$\frac{1120 - (1120 \times 28.74 \div 100)}{.000\,002\,59 \times 29.5^3 \times 13.5^2} = \frac{798.11}{12.16} = 65.63 \textit{ coefficient.}$$

peed of vessel being 10 knots per hour = 17.05 feet per second, power opel vessel at this speed = 65.63 × 17.05² = 19076.13, and IP exe

$$\frac{13 \times 17.05 \times 60}{33\,000} = 591.36.$$

	IP.	
of engines 1.5 lbs. upon 3848 sq. ins. × 13.5 revolu- ÷ 33 000 × 2	94.45	
ent. upon pressure of steam, less 2 lbs. above	60.45	
	201.6	
	172.14	
ssel	591.36	
	1120	

	HP.	Per cent. of Power.
Screw Propeller. Friction of engines	96.06	18.83
Friction of load	81.48	
" of screw surface and resistance of edges of blades	53.44	6.83
Slip of propeller	205.55	26.27
Absorbed by propulsion of vessel	375.92	48.04
	782.45	100

NOTE.—From experiments of Mr. Froude, he deduced that, as a rule, only 37 to · per cent. of whole power exerted was usefully employed.

With an auxiliary propeller, essential differences are in friction of surfaces and edges of blades of propeller and slip of propeller, being as 12 to 6.83 in excess in first case, and as 13.7 to 26.27 in second case, or 50 per cent. less.

Resistance of Bottoms of Hulls at a Speed of one Knot per Hour.

Smooth wood or painted	.01 lb.	Copper	.007 lb.
Smooth plank	.016 "	Moderately foul	.019 "
Iron bottom, painted	.014 "	Grass and small barnacles	.06 "

Sailing.

Ratio of Effective Area of Sails and of Vessel's Speed under Sail to Velocity of Wind.

COURSE.	Ratio of Effective Area of Sails.	Ratio of Speed of Vessel to Wind.	COURSE.	Ratio of Effective Area of Sails.	Ratio of Speed of Vessel to Wind.
Points of wind	.59	.33	Wind abeam	.82	.6
" abaft beam	.91	.5	" astern	1	.5
" of wind	.68	.5	" on quarter	.96	.66

Propulsion and Area of Sails.

Plain sails of a vessel are standing sails, excluding royals and gaff topsails.

Resistance of vessels of similar models but of different dimensions for equal speeds $= D^{\frac{2}{3}}$.

Hence $\frac{a}{a'} = \left(\frac{D}{D'}\right)^{\frac{2}{3}}$. *a and a' representing areas of sails of known and given vessels, and* D *and* D′ *their displacements in tons.*

ILLUSTRATION.—Assume D and D′ = 2400 and 1600.

Then $\left(\frac{2400}{1600}\right)^{\frac{2}{3}} = \sqrt[3]{1.5^2} = 1.31$, hence area of sails $a' = \frac{1}{1.31} = .763$ *per cent.*

In Vessels of Dissimilar Models.—Plain sail area should be a multiple of $D^{\frac{2}{3}}$.

Multiples for Different Classes of Vessels, R.

Sailing.		*Steamer.*
Ships of Line	100 to 120	Ships, iron-clad
Frigates	120 to 160	Frigates
Sloops		Sloops
Brigs		Brigs

English Yachts, designed for high speed, have multiples fro. nd when designed for ordinary speed from 130 to 180.

When Area of Sail to Wet Surface of Hull is taken.—American yacht atio of 2.7 to 1, and several English yachts nearly the same, while t— *was but 2 to 1.*

Location of Masts, etc. *Load-line* = 100.

Vessel.	Distance from Stem. Fore.	Main.	Mizzen.	Foot of Sail.*	Height of Centre of Effect above Water-line = Breadth.*
Ship.........	10 to 20	53 to 58	80 to 90	125 to 160	1.5 to 2
Bark.........	12 to 20	54 to 60	81 to 91	130 to 160	1.5 to 1.95
Brig.........	17 to 20	64 to 65	—	160 to 165	1.5 to 1.75
Schooner....	16 to 22	55 to 61	—	160 to 170	1.5 to 1.75
Sloop........	—	36 to 42	—	170 to 190	1.25 to 1.75

* Measured from Tack of Jib to Clew of Spanker or Mainsail.

Rake of Masts.

Ships.—Foremast 0 to .28 of length from heel, Main and Mizzen 0 to .5
Schooners.—Foremast .1 to .25, Mainmast .63 to .77. Sloops.—.08 to .11.

Area of Sails.

Sails.	3 Yards upon each Mast.	4 Yards upon each Mast.	Sails.	3 Yards upon each Mast.	4 Yards upon each Mast.
Jib............	.08	.08	Mizzenmast....	.127	.14
Foremast......	.295	.295	Spanker or Driver...	.081	.068
Mainmast......	.417	.417			

Proportional Area of Sails upon each Mast under above Divisions.

Sail.	Fore.		Main.		Mizzen.		Proportion to 1.	
Course................	.115	.097	.162	.138	—	—	.389	.33
Topsail................	.105	.09	.149	.127	.075	.063	.358	.303
Topgallant sail........	.075	.063	.106	.089	.052	.045	.253	.215
Royal..................	—	.045	—	.063	—	.032	—	.159
Spanker or Driver.....	—	—	—	—	.081	.068	—	—
Jib....................	.08	.08	—	—	—	—	—	—
	.375	.375	.417	.417	.208	.208	1	1

Balance of Sails.—Effect of jib is equal to that of all sails upon mainmast, and sails upon mizzenmast balance those of foremast.

Areas of sails upon masts of a ship should be in following proportion:

Fore.............. 1.414 | Main.................. 2 | Mizzen................1

When, therefore, main yard has a breadth of sail of 100 feet, fore yard should have 70.71 feet, and mizzen 50 feet; topgallant and royal yards and sails being in same proportion.

Angles of Heel for Different Vessels.

Approximately. $\frac{D\,M\,a}{H} = S$. D *representing displacement of vessel in lbs.* M *height of meta-centre above centre of gravity in feet, a angle of heel of vessel in circular measure,* and* H *height of centre of effect above centre of lateral resistance feet.*

Moment of sail should be equal to moment of stability at a defined angle heel.

	Angle.	Circular Measure.		Angle.	Circular Measure.
tes, etc.............	4°	.07	Schooners, etc.	6°	.105
ttes	5°	.087	Yachts..........	6° to 9°	.105 to .157

ILLUSTRATION— ... displacement 170 tons, height of meta-centre 6.75 feet ... el 9°; what should be area of sails?

... 2240 = 380 800 lbs. 9° = .107.

$$\frac{\ldots \times 6.75 \times .107}{36} = 7639.8 \textit{ sq. feet.}$$

* See rule, page 113.

Trimming of Sails.

'hat a vessel's sail may have greatest effect to propel her forward, it should 3o set between plane of wind and that of her course, that tangent of angle ıakes with wind may be twice tangent of angle it makes with her course.

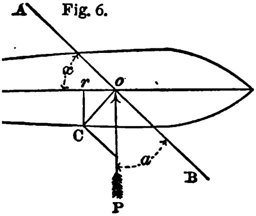
r, tan. $a = 2$ tan. b. *a representing angle of sail with wind, and b angle of sail course of vessel.*

Angles of Course and Sails with Wind.

nd ad.	Angle of Course.	Tangent.	Half Tangent.	Angles of Sail with Wind.	Angles of Sail with Course.	Wind Abaft.	Angle of Course.	Tangent.	Half Tangent.	Angles of Sail with Wind.	Angles of Sail with Course.
ıts.						Points.					
	45°	.562	.281	29° 18′	15° 42′	2	112° 30′	2.166	1.082	65° 13′	47° 17′
	56° 15′	.732	.365	36° 12′	20° 3′	3	123° 45′	2.737	1.368	69° 56′	53° 49′
	67° 30′	.923	.461	42° 43′	24° 45′	4	135°	3.562	1.781	74° 17′	60° 43′
am	90°	1.415	.707	54° 45′	35° 16′	6	157° 30′	7.511	3.754	82° 25′	75° 5′

Effective Impulse of Wind.

Fig. 6.



Let P o, Fig. 6, represent direction by compass and force of wind on sail, A B; from P draw P C parallel to A B, from o draw o C perpendicular to A B; o C is effective pressure of wind on sail A B, and r C, perpendicular to plane of vessel, is component of o C, which produces lateral motion, as heel and leeway, and $r\,o$ is component of o C, which propels vessel.

I sin. $a =$ P; P cos. $x =$ L; and P sin. $x =$ E. I *representing direct impact and* P *effective pressure of wind on sail,* L *effective impact producing leeway, and* E *effective impact which propels vessel.*

OTE.—The law as usually given is sin.². This is manifestly incorrect, as it gives ılts less than normal pressure for angles of small incidence. At an angle of innce of wind of 25°, the law of sin. is exact. Hence, although it may not be ;t at all angles, it is sufficiently so for practical purposes.

LUSTRATION I.—Assume wind 5 points ahead, and I = 100 lbs.

y preceding table angle of course with wind 56° 15′; hence angle of sail a, with d 36° 12′, as tan. 36° 12′ = 2 tan. 20° 3′, and angle x 56° 15′ − 36° 12′ = 20° 3′.

ıen, 100 × sin. 36° 12′ = 100 × .5906 = 59.06; 59.06 × cos. 20° 3′ = 59.06 × 4 = 55.48, and 59.06 × sin. 20° 3′ = 59.06 × .3426 = 20.23 *lbs.*

—Assume wind 4 points abaft, and I = 100 lbs.

ıen, 100 × sin.² 74° 17′ = 100 × .9626² = 92.66; 92.66 × cos. $\overline{180° - 74° 17' + 45°}$ 0° 43′ = 92.66 × .49 = 45.41, and 92.66 × sin. 60° 43′ = 92.66 × .8722 = 80.82 *lbs.*

To Compute Sailing Power of a Vessel.

F f sin. w, sin. s = P.

'o Compute Careening Power of a Sailing Vessel.

f sin. w, cos. s = P. F *representing area of sails in sq. feet, f force of wind in per sq. foot, w angle of wind to sails, and s angle of sails to co*

To Compute Angle of Steady H

Within a Range of 8°.

$\frac{\text{P E}}{\text{) M}}$ = sin. H. *a representing area of plain sail in sq. feet,* P ;

bs. per sq. foot, E *height of centre of effect above mid-draught, in ıt of hull, in lbs., and* M *height of meta-centre in feet.*

assumed at 1 *lb. per sq. foot, or that due to a brisk wind.*

LUSTRATION.—Assume a = 15 600, draught = 20, and E = 62; hı

D = 6 800 000, and M = 3.

hen $\frac{15\,600 \times 1 \times 72}{6\,800\,000 \times 3} = \frac{1\,123\,200}{20\,400\,000} = .05505 = 3° 10'$.

Course and Apparent Course of Wind.

Apparent course of a wind against sails of a vessel is resultant of actual course of wind and a course equal and directly opposite to that of vessel.

Fig. 7.

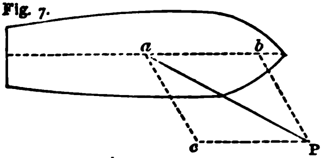


ILLUSTRATION.—If P, Fig. 7, represent direction by compass and force of wind, and $a\,b$ direction and velocity of vessel, from P draw P c parallel and equal to $a\,b$, join $c\,a$ and it will represent direction and force of apparent wind.

Or, $\frac{a\,c}{c\,P}$ = *ratio of velocity of apparent wind to that of vessel,* $\frac{a\,P}{c\,P}$ = *ratio of velocity of wind to that of vessel.*

Resistance of Air. (*Mr. Froude.*)

Resistance of wind to a vessel is estimated as equivalent to square of its velocity.

In a calm, resistance of air to a steamer = one thirty-fourth part of resistance of water, and when a steamer's course is head-to, and combined velocity of vessel and wind = 15 knots, resistance is one ninth of that of the water.

Resistance of air to a sq. foot of surface at right angles to course of a vessel is about .33 lb., and when surface is inclined to direction of wind, pressure varies as *sine* of angle of incidence.

Mean of angles of surface of a steamer exposed to wind may be taken at 45°; hence their resistance is about .25 lb. per sq. foot when wind has a velocity of 10 knots per hour.

If sectional area of a steamer's hull above water is 750 sq. feet, resistance to air at a speed of 10 knots in a calm would be 750 × .25 = 187.5 lbs., and resistance to smoke-pipe, spars, and rigging (brig rigged) would be 201 lbs.

Leeway.

Angle of Leeway in good sailing vessels, close hauled, varies from 8° to 12°, and in inferior vessels it is much greater.

Ardency is tendency of vessel to fly to the wind, a consequence of the centre of effort being abaft centre of lateral resistance.

Slackness is tendency of vessel to fall off from the wind, a consequence of the centre of effort being forward centre of lateral resistance.

Results of Experiments upon Resistance of Screw-propellers, at High Velocities and Immersed at Varying Depths of Water.

Immersion of Screw.	Resistance.	Immersion of Screw.	Resistance.	Immersion of Screw.	Resistance.
Surface.	1	2 feet.	7	4 feet.	7.8
1 foot.	5	3 "	7.5	5 "	8

Slip of Propeller, 15 per cent.; of *Side-wheel (feathering blades),* and taking axes of blades as the centre of pressure, 23 per cent.

Freeboard.

deck stringer to surface of water. Depth of Hold from under side of spar deck to top of ceiling.

Ft.	Hold.	Per Ft.	Hold.	Per Ft.	Hold.	Per Ft.	Hold.	Per Ft.
	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	In.
	16	2.75	20	3.125	24	3.375	[illegible]	[illegible]
	18	3	22	3.25	26	3.5	[illegible]	[illegible]

Plating Iron Hulls.

:T. D *representing displacement in tons*, L *length of hull*, *b breadth, and*

r, $.05 f \sqrt{d} = T$. *f representing distance between centres of frames, and* ›*late below load-line, all in feet, and* T *thickness of plate in ins.*

Masts and Spars. *Diameter for Dimensions.*

:s...........	at spar deck.	Jib-boom.............	at bowsprit cap.
....	" stem.	Yards.................	in middle.
....	" lower cap.	Gaffs..................	at inner end.
masts.......	" topmast cap.	Main and Spanker booms	at taffrail.

main masts, when of pieces, 1 inch for each 3 to 3.25 feet of whole zzenmast .66 diameter of mainmast. Masts of one piece 1 inch for each 'eet of whole length.

, depth, equal diameter of mainmast; width, diameter equal to foremast.

›re topmasts.......	1 inch for each	3 to 3.25	feet of whole length.
nast..............	1 " " "	3.25 " 3.33	feet of whole length.
nasts.............	1 " " "	3.25 " 3.33	feet of whole length.
s.................	1 " " "	3.66	feet of whole length.
ɔoles..............	1 " " "	2.87	feet of whole length.
....	1 " " "	2 ft. of length beyond bowsprit cap.	
ıain yards.........	1 " " "	4	feet of whole length.
ls.................	.875 " " "	4	feet of whole length.
Topgallant, and rds..............	1 " " "	5	feet of whole length.
panker booms.....	1 " " "	3.5	feet of whole length.
....	1 " " "	3.5 to 4	feet of whole length.
il yards and booms.	1 " " "	4.5 to 4.75	feet of whole length.

Rudder Head. (*Mackrow.*)

$.196\ C\ D^3 = M$; $\sqrt[3]{\frac{T}{.196\ C}} = D$; and $\frac{A\ v^2}{2400} = P$. P *representing press-* *er when hard over, in tons, d distance of geometrical centre of rudder from* *on, in ins.,* T *stress on head, and* M *moment of resistance of head, both in* *immersed area of rudder in sq. feet, v velocity of water passing rudder* *hour, and* C *coefficient* $= 3.5$ *per sq. inch for Iron, and* $.125$ *for Oak.*

:ION.—Assume area of wooden rudder 24 sq. feet, distance of its geomet- from centre of pintles 2 feet, and velocity of water 10 knots.

$\frac{\ ^2}{} = 1$ *ton.* $1 \times 2 \times 12 = 24$ *inch-tons.* $\sqrt[3]{\frac{24}{.196 \times .125}} = 9.93$ *ins.*

Memoranda.

– A man requires in a vessel a displacement of 488 lbs. per month, for res, water, fuel, etc., in addition to his own weight, which is estimated A man and his baggage alone averages 225 lbs.

;o feet in length, 32 beam, and 22.83 in depth, or 664 tons, C. H. (O. M.), 2540 square and 484 round bales of cotton. Total weight of cargo ., equal to 4.57 bales, weighing 1889 lbs., per ton of vessel.

lt ship of 1625 tons, N. M., can carry 1800 tons' weight of cargo, or stow f pressed cotton.

on steamboat *John Stevens*—length 245 feet, beam 3 ld ght of iron 239 440 lbs. And of one other—length 1 eet deep; weight of iron 159 190 lbs.

hull of a vessel with an iron frame and oak planking (t ı hull entirely of wood, is as 8 to 15.

ıll weighs about 45 per cent. less than a wooden hull.

254 feet in length, 42 beam, and 23.5 hold, 1800 tons regis ons cargo at a draught of 22 feet. Weight of hull in ser

ight per Sq. Foot per Month of Metalling of a Vessel's Bott

›61 lb.; Muntz metal .0045 lb.; Zinc .007 lb.; and Iron .o

m between Iron and Steel plated Steamers.—In a vessel *t, hull of steel*-plated will weigh 320 tons less = 6.66 per c

Pencil. Rays which meet in a focus and are taken ...

Object.—As regards comparative dimensions ... *similar triangles*, that their linear dimensions are directly ... from centre of curvature.

a ray is diverted from vacuum into any medium, the ratio is greater ity, and is termed *absolute index* or *index of refraction*.

Mean Indices of Refraction.

eous humor	1.339	Glass, lead, 3 flint	2.03
stalline lens, under	1.379	" lead 2, sand 1	1.99
" " central	1.4	" " 1, flint 1	1.78
l	2.6	Ice	1.31
nt	1.57	Quartz	1.54

dices of other substances, see page 584.

increases refractive power of fluids and glass.

cal Angle.—Its sine is reciprocal of index of refraction, the incident ng in the less refractive medium.

$$\text{Thus, } \frac{1}{\text{Index}} = \textit{sin. of angle.}$$

al Angle is measure of length of image of a straight line on the retina.

l Reflection is when rays are incident in the more refractive medium, ngle greater than the critical angle.

age.—An appearance as of water, over a sandy soil when highly heated sun.

stic Curves or Lines are the luminous intersections from curve lines, as on any reflective surface in a circular vessel.

To Compute Index of Refraction.

$\frac{I}{R} = \textit{Index}$. *I representing angle of incidence, and* R *that of refraction.*

To Compute Refraction.

cave-Convex and Meniscus.—Effect of a concave-convex in refracting is same as that of a convex lens of same focal distance, and that of a cus is same as a concave lens of same focal distance.

niscus, with parallel rays $\frac{2\,R\,r}{R-r} = F$.

gnifying Power.—In *Telescopes* the comparison is the ratio in which it ently increases length. In *Microscopes* the comparison is between the as seen in the instrument and by the eye, at the least distance of , which is assumed at 10 ins., and the magnifying power of a micro- is equal to the distance at which an object can be most distinctly ex- d, divided by the focal length of the lens or sphere.

ear power is number of times it is magnified in length, and *Super-*, number of times it is magnified in surface.

gnifying power of microscopes varies, according to c from 40 to 350 times the linear dimensions of object, o times its superficial dimensions.

parent Area.—As areas of like figures are as the squares isions, the apparent area of an object varies as square o nded by its diameter.

e number expressing *Magnification of Apparent Area* e of magnifying power as above described.

STRATION.—*If diameter of a sphere subtends 1° as seen by the n through a telescope, the telescope* is said to have a power of 1.

To Compute Elements of Mirrors and Lenses.

Mirrors. *Spherical Concave.** $\frac{O\,r}{r-2\,l}=D$; $\frac{l\,r}{r-2\,l}=L$.

Spherical Convex.† $\frac{O\,r}{2\,L+r}=D$; $\frac{L\,r}{2\,L+r}=l$. *Parabolic Concave.* $\frac{d^2}{16\,h}=F$

Unequally Convex.‡ $\frac{2\,B\,r}{R+r}=F$. *Plano-Convex.*§ $2\,B-.66\,t=F$.

Hyperbolic Concave.‖ *Elliptic Concave.*¶ **Sphere.** $\frac{I}{2\,I-1}=F$.

O representing object = 1, r radius of convexity, l and L length or distance of object from vertex of curve, and from external vertex, D dimension of object, d diameter of base, F focal distance, and h depth of mirror in like dimensions, I index of refraction, and t thickness of lens.

Illustration 1.—Before a concave mirror of 5 feet radius is set an object at 1.5 feet from vertex of curve; what is ratio of apparent dimension of image, and what is length of and distance of object from external vertex? Object = 1.

$$\frac{1\times5}{5-2\times1.5}=2.5\textit{ feet, and }\frac{1.5\times5}{5-2\times1.5}=3.75\textit{ feet.}$$

2.—If object is set at 4.5 feet from vertex of a like mirror, what is length of and distance of inverted object from internal vertex?

$$\frac{1\times5}{2\times4.5-5}=1.25\textit{ feet, and }\frac{4.5\times5}{2\times4.5-5}=5.625\textit{ feet.}$$

3.—Before a convex mirror of 3.5 feet radius is set an object at 3 feet from vertex of curve; what is length of and distance of object from external curve?

$$\frac{1\times3.5}{2\times3+3.5}=.368\textit{ foot, and }\frac{3\times3.5}{2\times3+3.5}=1.105\textit{ feet.}$$

4.—A parabolic reflector has a depth of 1.25 feet and a diameter of 2 feet; what is its focal distance from vertex of internal curve?

$$\frac{2^2}{16\times1.25}=.2\textit{ feet or }2.4\textit{ ins.}$$

Lenses. *Double Convex.* $\frac{R\,r}{m-1\times\overline{R+r}}=F$. *When* $R=r$ $\frac{r}{2\,m-1}=F$.

$\frac{o\,F}{F-l}=D$; $\frac{l\,F}{F-l}=L$; $\frac{S+F}{F}=P$; $\frac{O\,F}{F-O}=V$; and $\frac{S\,F}{S+F}=0$.

Double Concave. $\frac{R\,r}{m-1\times\overline{R+r}}=F$; $\frac{o\,F}{F+L}=D$; $\frac{F\,o-D}{D}=L$; and $\frac{L\,F}{L+F}=$

Optical centres are in centres of lens. *Plano-Convex* and *Plano-Concave.* $\frac{r}{m-1}=F$. Optical centres are respectively centres of convex and concave surfaces. *Convex Concave* (*Meniscus*) and *Concavo-Convex.* $\frac{R\,r}{m-1\times\overline{R-r}}=F$

Optical Centres. Convex Concave. Delineate lens in half section, draw R from its centre to circumference of lens (intersection of radii), draw r parallel thereto and extending to its circumference, connect R and r at these external points of contact with circumference and external curve, extend line to axis of lens, and point of contact is centre required. *Concavo-Convex.* Proceed in like manner, but in this case r extends to, or delineates, the inner surface of the lens, and point of contact with axis is centre required.

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* D or image disappears when $l=.5\,r$. † *When O is beyond* F, it will be inverted, and $\frac{L\,r}{2\,D+r}=l$. ‡ When equally convex $F=R$. § When convex side is exposed to ... and when parallel rays fall upon plane side, $F=2\,R$. ‖ Rays of light, heat, or sound, ... focus of a hyperbola, will diverge from its concave surface, ¶ and when from the ... will be refracted by surface of the other.

When object is beyond focal distance (F), its image (D) will be inverted, as $\frac{O\,F}{l-F}=D$, and $\frac{L\,F}{L-F}=l$.

representing magnifying power of lens, S *limit of normal sight,* 10 *to* 12 *ins. for* ..r-*sighted eyes and* 6 *to* 8 *for near-sighted, ordinarily* 10 *ins.,* V *limit of distinct* ..sion, O *extreme distance of object from optical centre at distinct vision, and* m *index* .. *refraction.*

ILLUSTRATION 1.—If a double convex lens of flint glass has radii of 6 and 6.25 ins., ..hat is its focal distance? Index of refraction = 1.57, see page 584.

$$\frac{6 \times 6.25}{1.57 - 1 \times \overline{6 + 6.25}} = 5.37 \textit{ ins.}$$

2.—If a double concave lens has a focal distance of 2 ins., and object is 6 ins. from ..rtex of curve, what is its dimension and what is its distance from vertex of inner ..rve?

$$\frac{6 \times 2}{2+4} = 2 \textit{ ins.}, \text{ and } \frac{4 \times 2}{4+2} = 1.33 \textit{ ins.}$$

3.—If focal distance of a single microscope is 4 ins., what is its limit of distinct ..sion, and what its magnifying power? O = 2.857 *ins.*

$$\frac{2.857 \times 4}{4 - 2.857} = 10 \textit{ ins.}, \text{ and } \frac{10+4}{4} = 3.5 \textit{ times.}$$

Telescopes, Opera-glasses, etc.

$D : o = F : f$; $\;of \div F = D$, and $\frac{L\,F}{f} = l$; $\;\frac{L\,f^*}{L-f} \pm \frac{s\,F}{s+F} = F + f$. *f representi..g length of focal distance from object lens.*

ILLUSTRATION.—Principal focal distance of ocular lens of a telescope is .9 in., of ..bjective lens 90 ins.; what is its magnifying power?

$$90 \div .9 = 100 \textit{ times the object.}$$

PILE-DRIVING.

Effect of the impact of the ram of a pile-driver is as the square root of .. velocity or height of its fall. Thus the theoretical velocity of fall is as $\sqrt{2\,g\,h}$ or $8\sqrt{h}$.

The impact or dynamic effect of the blow of a ram on a pile cannot be ..termined with exactness, so long as it yields under the blow, as the yield-..g cushions it and reduces its effect.

By my experiments in 1852 to determine the dynamic effect of a falling body, I ..und it to be far greater than that given by the formula $\sqrt{2\,g\,h}$, and upon a late ..petition of them, under improved conditions of the instrument of registry, I find ..to be for one pound falling two feet, 52 pounds. One pound falling 2 feet has a ..locity of 11.31 feet per second, but its dynamical effect or *vis viva* was 52 pounds, .. 4.6 times the velocity.

Observation and tests of the sustaining power of piles, at different locations and ..der different conditions, gave it as 2, 3, and 3.7 to 1 times that deduced by the ..rmula $8\sqrt{h}$, which was but the net effect, or capacity, of ram, le.. ..ion of .. operation.

Wm. J. McAlpine in his operation on the foundations of the dry .. ..rd, Brooklyn, estimated the effect of a ram weighing 2240 lbs., ...usal, at 224 000 lbs., or 2.28 times that given by the formula *w*..

Essayists present a variety of formula, which differ in form. ..ratively simple, while others embrace diameter, length, weig.. ..a, depth driven by last blow in feet or in inches, and Modulus o.. ..terial of the pile, together with various factors for results.

When the losses of effect in the operation of a pile-driver are d.. .., friction of ram in the guides of the leader, and of the hoistin.. .. sheave and over drum (ascertained by experiment with a ver..

* + for telescopes and — for opera-glasses, etc.

be equal to .2 foot of penetration: with a light ram it would be materially ... the cushioning of it on head of a pile, however square it may be dressed ... want of verticality both of ram in falling and of plane of the pile to the blow ... consequent lateral vibration of it, the buckling of it in driving, the frequent ... ting of it on a boulder, and the condition of soil, whether dry, moist, or wet ... is imbedded or partially exposed to the air, or wholly immersed in wet soil ... water, and the integrity of the driving—they furnish the elements in determina... tion of a *coefficient of safety.*

Opposed to these effects is that of the subsidence of the soil around a pile ... has been disturbed in driving, the effect of which, under favorable conditio... soil, has approached to that of the resistance of the pile at its final blow.

The following formula is constructed on the basis of a pile being d... to a depression of one inch or less, as all estimates based upon a great... pression are not only comparatively valueless, in consequence of the ... ioning of the ram, but if piles are not driven to such depression their ... is decreased, and a greater number are rendered necessary to suppor... weight to be imposed upon them, and in it I have omitted an element ... is universally given in others, that of the last depression of a pile as a ... sor, as I not only fail to recognize its connection, but hold its introdu... erroneous.

To Compute Safe Load of a Pile Driven to a Depression of 1 Inch or Less.

$4\,W\,8\,\sqrt{h} = L$. *W representing weight of ram, and* L *load, both in lbs., ... height of fall in feet.*

From which result is to be deducted a factor of safety representing the f... and losses of effect.

Hence, the formula: $\frac{4\,w\,8\,\sqrt{h}}{C} = L$, or *safe load in pounds.*

For C, or coefficient of safety, in consideration of the several losses of eff... cited, and especially that of brooming of the heads of a pile, it is assumed at 3 to 6, according to the soil and the integrity of the driving.

Eliminating the numerator 4 and correspondingly reducing the 3 and 6, th... mula is, $\frac{w\,8\,\sqrt{h}}{.75 \text{ to } 1.5} = L$.

ILLUSTRATION.—Assume an ordinary pile driven in firm soil by a ram of 20... weight, falling 25 feet, with a final depression of .5 inch, and coefficient of ... what would be its safe load?

$$\frac{2000 \times 8\sqrt{25}}{1.25} = \frac{2000 \times \overline{8 \times 5}}{1.25} = 64\,000 \text{ lbs.}$$

In practice, in the determining the capacity of a range of piles, it is p... to reduce the result obtained by the formula, to meet incidental effec... negligence in driving, in the superintendence of it, and the frequent an... observed splitting or crushing of a pile on a stone or boulder.

A heavy ram and a low fall is most effective condition of operatin... pile-driver, provided height is such that force of blow will not be expe... in merely overcoming friction of leader and inertia of pile, and at same ... not from such a height as to generate a velocity which will be essen... expended in crushing fibres of head of pile.

When the soil is very soft or wet, concrete should be laid between ... heads of the piles to a depth of from 1.5 to 3 feet.

When the soil is of fine sand or light gravel, piles may be set two f... from their centres, but if it is saturated with moisture, a greater distan... necessary, otherwise small piles are liable to be disturbed by larg...

(Continued on page 972.)

Pile-sinking.

itchell's Screw Piles are constructed of a wrought-iron shaft of suitable eter, usually from 3 to 8 ins., with 1.5 turns of a cast-iron thread of . 1.5 to 3 feet diameter.

draulic Process is effected by the direction of a stream of water under ure, within a tube or around the base of a pile, by which the sand or ι is removed.

ieumatic and Plenum Process.—For illustration and details, see Traut-'s Engineer's Pocket-book, 647–8. *New Edition.*

·. *Whewell* deduced the following results:

A slight increase in hardness of a pile or in weight of a ram will con-ably increase distance a pile may be driven.

Resistance being great, the lighter a pile the faster it may be driven.

Distance driven varies as cube of the weight of ram.

Relative Resistance of Formations to Driving a Pile.

....	100	Hard clay............	60	Light clay and sand...	35
and gravel......	83	Clay and sand.........	45	River silt.............	25

PNEUMATICS.—AEROMETRY.

otion of gases by operation of gravity is same as that for liquids. e or effect of wind increases as square of its velocity.

a volume of air represented by 1, and of 32°, is heated t degrees without ning a different tension, the volume becomes $(1 + .002\,088\,t) = V$; and requires a temperature in excess of t' 32°, it will then assume volume $.002\,088\,\overline{t' - 32°})$. All aeriform fluids follow this law of dilatation as as that of compression proportional to weight.

hen air passes into a medium of less density, its velocity is determined ifference of its densities. Under like conditions, a conduit will discharge 5 times more air than water.

Compute the Degree of Rarefaction that may be effected in a Vessel.

it quantity of air in vessel, tube, and pump be represented by 1, and ortion of capacity of pump to vessel and tube by .33; consequently, it ains .25 of the air in united apparatus.

pon the first stroke of piston this .25 will be expelled, and .75 of original itity will remain; .25 of this will be expelled upon second stroke, which qual to .1875 of original quantity; and consequently ther iratus .5625 of original quantity. Proceeding in this manı le is deduced:

o. of Strokes.	Air Expelled at each Stroke.	Air Remaining
1	$.25 = .25$	$.75 = .75$
2	$\frac{3}{16} = \frac{3}{4 \times 4}$	$\frac{9}{16} = \frac{3 \times 3}{4 \times 4}$
3	$\frac{9}{64} = \frac{3 \times 3}{4 \times 4 \times 4}$	$\frac{27}{64} = \frac{3 \times 3 \times 3}{4 \times 4 \times 4}$

so on, multiplying air expelled at preceding stroke by 3, and r 4; and air remaining after each stroke is ascertained by m. *remaining after preceding* stroke by 3, and dividing it by 4.

Distances at which Different Sounds are Audible.

	Feet.	Miles.
A full human voice speaking in open air, calm	460	.0
In an observable breeze, a powerful human voice with the wind can be heard	15840	3
Report of a musket	16000	3.0
Drum	10560	2
Music, strong brass band	15840	3
Cannonading, very heavy	575000	90

In Arctic Ocean, conversation has been maintained over water a distance of 6696 feet.

In a conduit in Paris, the human voice has been heard 3300 feet.

For an echo to be distinctly produced, there must be a distance of 55 feet.

Coefficients of Efflux of Discharge of Air. (*D'Aubuisson.*)

Orifice in a thin plate	.65	[illegible]
Cylindrical ajutage	.93	[illegible]
Slight conical ajutage	.94	[illegible]

To Compute Volume of Air Discharged through an Opening into a Vacuum, per Second.

$a\,C\sqrt{2\,g\,h} = V$ *in cube feet.* *a representing area of opening in square feet, C coefficient of efflux, and* $\sqrt{2\,g\,h} = 1347.4$, *as shown at page* 428.

ILLUSTRATION.—Area of opening 1 foot square, and $C = .707$.

Then $1 \times .707 \times 1347.4 = 952.61$ *cube feet.*

Inversely, $V \div a$ = *velocity in feet per second.*

Velocity and Pressure of Wind.

Pressure varies as square of velocity, or $P \propto V^2$.

$V^2 \times .005 = P$; $\sqrt{200\,P} = V$; $v^2 \times .0023 = P$; and $.0023\,v^2 \sin. x^2 = P$.

V representing velocity in miles per hour, v in feet per second, P *pressure in lbs. per sq. foot, and x angle of incidence of wind with plane of surface.*

Table deduced from above Formulas.

Velocity per Hour.	Velocity per Minute.	Pressure on a Sq. Foot.	Character of the Wind.	Velocity per Hour.	Velocity per Minute.	Pressure on a Sq. Foot.	Character of the Wind.
Miles.	Feet.	Lbs.		Miles.	Feet.	Lbs.	
1	88	.005	Barely observable.	25	2200	3.125	Very brisk.
2	176	.02	Just perceptible.	30	2640	4.5	High wind.
3	264	.045		35	3080	6.125	
4	352	.08	Light breeze.	40	3520	8	Very high wind.
5	440	.125	Gentle, pleasant wind.	45	3960	10.125	Gale.
6	528	.18		50	4400	12.5	Storm.
8	704	.32		60	5280	18	Great storm.
10	880	.5	Fresh breeze.	80	7040	32	Hurricane.
15	1320	1.125	Brisk blow.	90	7920	40.5	Tornado.
20	1760	2	Stiff breeze.	100	8800	50	

ILLUSTRATION.—What is pressure per sq. foot, when wind has a velocity of 18 miles per hour?

$18^2 \times .005 = 1.62$ *lbs.*

To Compute Force of Wind upon a Surface.

$= P$. *v representing velocity of wind in feet per second, a area of*

angle of incidence of wind.

d has been observed to have had a velocity of 150 miles

Greenwich Observatory for a period of 20 years was

Force of wind upon a surface, perpendicular to its direction, has been ol served as high as 57.75 lbs. per sq. foot; velocity $=$ 159 feet per second.

Dr. Hutton deduced that resistance of air varied as square of velocit nearly, and to an inclined surface as 1.84 power of sine $\times$ cosine.

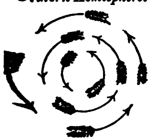
Figure of a plane makes no appreciable difference in resistance, but cor vex surface of a hemisphere, with a surface double the base, has only ha the resistance.

At high velocities, experiments upon railways show that the resistanc becomes nearly a constant quantity.

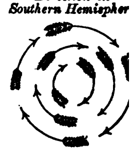
Course of Wind.

Cyclones.

Direction in Northern Hemisphere.



Direction in Southern Hemispher



Wind has its direction nearly at right angles to line between points of highest and lowest pressure of air, or barometer readings, and its course is with the point of lowest pressure at its left, and its velocity is directly as difference of the pressures.

In Northern Temperate zone, winds course around an area of low pressur n *reverse* direction to course of hands of a watch, and they flow away fror location of high pressure, and cause an apparent course of the winds in di rection of course of the hands.

To Compute Resistance of a Plane Surface to Air.

$.0023\, a\, v^2 = P$ *in lbs.* *a representing area of plane in sq. feet, v velocity in direc tion of wind in feet per second,* $+$ *when it moves opposite, and* $-$ *when with the wind*

When Barometer Pressure $=$ *30 Lbs.*

(C. F. Martin, U. S. S. S.)

$.004\, a\, V^2 = P$. V *representing velocity of wind in miles per hour, and a area of pressure in sq. feet.*

To Compute Height of a Column of Mercury to induce an Efflux of Air through a given Nozzle.

Barometer assumed at 2.46 feet $=$ *29.52 ins., and Temperature 52°.*

$\frac{P^2}{48.073^2\, d^4} = H$, and $48.073\, d^2 \sqrt{H} = P$. *d representing diameter of nozzle and* H *height of column of mercury, both in feet, and* P *volume of air in lbs. per one second.*

Illustration.—Assume $d = .19$, and $P = .7$ lbs.

$$\frac{.7^2}{48.073^2 \times .19^4} = .1626 \text{ foot.} \quad 48.073 \times .19^2 \sqrt{.1626} - -$$

To Compute Pressure or Weight of Air u Height of Barometer and Temperature, I One Second.

$30.787\, d^2 \sqrt{B\, \frac{b+B}{t}} =$ *pressure in lbs.* Or, $48.073\, d^2 \sqrt{B} = lb$

height of barometer in external air, B *manometer or pressure of a. mercury, both in feet, and t temperature of air or gas in degrees.*

Illustration.—Assume $b = 2.5$ feet; $d = .25$ foot; $B = .1$ foot; an

Then $30.787 \times .0625 \sqrt{.1 \times \frac{2.5 + .1}{1.055}} = 1.924 \times \sqrt{.2465} = .9543$ lbs.

To Compute Temperature for a given Latitude and Elevation.

$82.8 \cos. l - \overline{.001\,981\,E - .4} = t$. E *representing elevation in feet.*

ILLUSTRATION.—Assume $l = 45^\circ$; cos. $= .707$; and $E = 656$ *feet.*

Then $82.8 \times .707 - \overline{.001\,981 \times 656 - .4} = 58.54 - \overline{1.299 - .4} = 58.54 - .899 =$ 57.641.

To Compute Volume of Air or Gas Discharged through an Opening and under a Pressure above that of External Air.

Air. $1347.4\, C \frac{d^2}{b} \sqrt{B\,(b' + B)\,T} = V$ *in cube feet per second.*

$T = 1 + .002\,22\,(t - 32^\circ)$, and $b' = 2.5 - .000\,09$ *elevation.*

Or, $621.28\, d^2 \sqrt{B} = V$.

ILLUSTRATION.—What would be volume of air that would flow through a nozzle .246 foot in diam. from a reservoir under a pressure of .098 foot of mercury, into air under a barometric pressure of 2.477 feet, temperature of air 55.4°, location of latitude, and at an elevation of 650 feet above level of sea?

$C = .75$; $b' = 2.5 - .000\,09 \times 650 = 2.4415\ (2.44)$; and $T = 1.0502$.

Then $1347.4 \times .75 \frac{.246^2}{2.477} \sqrt{.098\ (2.44 + .098) \times 1.0502} = 24.689 \times \sqrt{.2617} =$ [illegible] *cube feet.*

When Densities of External Air and that in Reservoir are Equal.

$1347.4\, C \frac{d^2}{b'} \sqrt{B\,(b + B)\,T} = V$. b' *representing height of mercury in reservoir.*

Gas. $\frac{4231}{\sqrt{p}} \sqrt{\frac{B\,d^5}{L + 42 \times d}} = V$. p *representing specific gravity of gas compared with air, and L length of pipe or conduit in feet.*

ILLUSTRATION.—If a pipe .05 feet in diameter and 420 feet in length, communicates with a gasometer charged with carburetted hydrogen (illuminating gas), under a water pressure as indicated by a manometer of .1088 foot, what would be the discharge per second?

$d = .05$ *foot;* $L = 420$ *feet;* and $B = \frac{.1088}{13.6^*} = .008$ *foot.* Specific gravity of gas .5625.

$$\frac{4231}{\sqrt{.5625}} \sqrt{\frac{.008 \times .05^5}{420 + 42 \times .05}} = \frac{4231}{.75} \sqrt{\frac{.000\,000\,002\,500\,0}{420 + 2.1}} = .013\,71 \text{ cube foot.}$$

Resistance of Curves and Angles.—Curves and angles increase resistance to discharge of air or gas very materially. By experiment of D'Aubuisson 7 angles of 45° reduced discharge of gas one fourth.

To Compute Diameter of Discharge-pipe or Nozzle.

When Length and Diameter of Pipe, Volume, and Pressure are given.

$$\sqrt[4]{\frac{42\, V^2\, d^5}{4230^2\, B\, d^5 - L\, V^2}} = d' \text{ in feet.}$$

ILLUSTRATION.—If a pipe 1000 feet in length, and .4 foot in diameter, leads to a reservoir of air, under a mercurial manometric pressure of .18 foot, what diameter must be given to a nozzle to discharge 4 cube feet per second?

Then $\sqrt[4]{\frac{42 \times 4^2 \times .4^5}{4230^2 \times .18 \times .4^5 - 1000 \times 4^2}} = \sqrt[4]{\frac{6.881\,28}{32\,980.19 - 16\,000}} = \sqrt[4]{.000\,405\,2} =$ [illegible] *foot* $= 1.703$ *ins.*

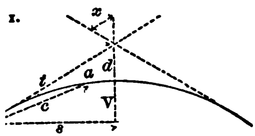
Two gases flowing through equal orifices, and under equal pressures, ratio of square roots of their respective densities.

* Specific gravity of mercury compared with water.

RAILWAYS.

To Define a Curve.—Fig. 1. (*Molesworth.*)

1.



$\frac{1719\,c}{a}$ or $t\ \overline{\tan.\ x} = R$; R (cotan. x) $= t$;

$\frac{1719\,c}{R} = a$; R (cosec. $x - 1$) $= d$;

R (cosin. x) $= s$; R (coversin. x) $= V$;

$\frac{5400 - x}{a} = n$, and $(5400 - x)\ .000\,582\ R = l$.

presenting any chord, t length of tangent, d distance of centre of curve from in- ction of tangents, s half chord of curve, and l length of curve, all in like dimensions, ngential angle of c in minutes, n number of chords in curve, and x half angle of ·section, but in formulas for number of chords and length of curve to be expressed inutes.

LUSTRATION.—Assume radius 900 and chord 400 feet; angle of intersection = 44′ = 764 minutes, and $x = 56°\ 15'\ 5''$.

ngent of 56° 15′ 5″ = 1.496 73. Cotangent = .668 14.

$\frac{19 \times 400}{764} = R = 900$ *feet;* $\frac{1719 \times 400}{900} = 764$ *minutes;* $900 \times .668\,14 = t =$ 33 *feet;* $900 \times \overline{1.202\,69 - 1} = d = 182.42$ *feet;* $900 \times .555\,55 = s = 500$ *feet;* $\times .168\,33 = V = 151.5$ *feet;* $\frac{5400 - 3379}{764} = 2.645$ *times*, and $.000\,582 \times 900 \times \overline{-3379} = 1058.6$ *feet.*

Tangential Angles for Chords of One Chain.

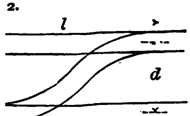
us of ve.	Tangential Angle.	Radius of Curve.	Tangential Angle.	Radius of Curve.	Tangential Angle.	Radius of Curve.	Tangential Angle.
ins.		Chains.		Chains.			
5	5° 43.8′	15	1° 54.6′	40	42.97′	1 mile	21.48′
8	3° 34.87′	20	1° 25.95′	45	38.2′	1.25 mil's	17.19′
9	3° 11′	25	1° 8.76′	50	34.38′	1.5 miles	14.33′
0	2° 51.9′	30	57.3′	60	28.65′	1.75 "	12.28′
2	2° 23.25′	35	49.11′	70	24.55′	2 "	10.74′

TE.—Angle for 2 chain chords is double angle for 1 chain chords. Angle for .5 n chords is .5 the angle for 1 chain chords.

rves of less than 20 chains radius should be set out in .5 chain chords. Curves ore than 1 mile radius may be set out in 2 chain chords.

gles in above Table are in degrees, minutes, and decimals of minutes.

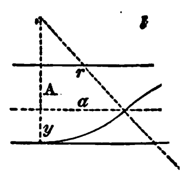
2.



Sidings.

$2\sqrt{d\,R - (.5\,d)^2} = l$. R *representing radius of curve, l length of curve over points, and d distance between tracks, all in feet.*

3.



urn-out of Unequal Radii.

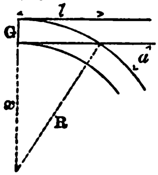
$\frac{r\,x}{+r} = y$; $x - y = z$; $a + b = l$; $r - y = A$;

$\overline{(r + A)} = a$; $R - z = B$; $\sqrt{z\,(R + B)} = b$.

and r representing radii of the curves re- ively as to length, x distance between outer of tracks and other symbols as shown, all et.

Points and Crossings.

Fig. 4.



$\sqrt{(R+x)\,G}=l$; $\frac{l}{R}=\sin.\,a$; $\frac{G}{\text{ver. sin. } a}=R$. R representing radius of curves, G gauge of road, a angle of crossing, and $x=R-G$, all in feet.

In horizontal curves, width required for clearance of flange of wheel, and for width of rail at heel of switch render it necessary to make an allowance in length of l as ascertained by formula.

For other diagrams and formulas, see Molesworth's Pocket-book, pp. 208–18, 21st edition.

To Compute Tangential Angle for Curves. $\frac{1719\,c}{R}=a$.

c representing chord in feet, and a angle in minutes.

ILLUSTRATION.—What is angle for a curve with a radius of 900 feet, and a chord of 400 feet?

$$\frac{1719\times400}{900}=764 \text{ minutes.}$$

Curving of Rails.

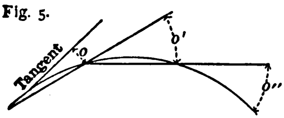
$\frac{1.56\,l^2}{R}=v$. *l representing length of rail in feet, v versed sine at centre, when curved, in ins.*

ILLUSTRATION.—What is curve for a rail 20 feet in length, with a radius of 900 feet?

$$\frac{1.5\times20^2}{900}=.666 \text{ ins.}$$

Curves by Offsets in Equal Chords.

Fig. 5.



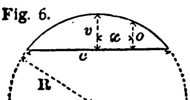
$\frac{\text{Chord}^2}{2\,R}=o$ *offset.* $\frac{\text{Chord}^2}{R}=2, o$ offset.

ILLUSTRATION.—Assume chords 150, and radius 900 feet.

$\frac{22\,500}{2\times900}=12.5$ *feet;* $\frac{22\,500}{900}=25$ *feet.*

To Compute Versed Sines and Ordinates of Curves.

Fig. 6.



$R-\sqrt{R^2-(.5\,C)^2}=v$; $\frac{(.5\,C)^2}{v}+v=D$;

$\sqrt{R^2-x^2}-(R-v)=o$. D *representing diameter of circle, and v versed sine of curve.*

ILLUSTRATION.—Assume radius 900, and chord 400 feet.

$900-\sqrt{810\,000-40\,000}=900-877.5=22.5$ *feet.*

Relation of Base of Driving or Rigid Wheels to Curves.

$\frac{R}{G}=B$. R *representing minimum radius of curve,* G *gauge of road, and* B base *in feet.*

To Compute Elevation of Outer Rail.

For any Radius or Combination of Curve with Straight Line.

— e. V *representing velocity of train in feet per second,* G *gauge of road, both in feet, the versed sine of which = elevation in ins.*

On Curves.

...enting elevation of outer rail in ins.

Radii of Curves set out in Tangential Angles.

;le for ›rd of Feet.	Radius of Curve.	Angle for Chord of 100 Feet.	Radius of Curve.	Angle for Chord of 100 Feet.	Radius of Curve.	Angle for Chord of 100 Feet.	Radius of Curve.
′	Feet.	° ′	Feet.	° ′	Feet.	° ′	Feet.
30	5729.6	2 30	1145.9	4 30	636.6	6 30	440.7
	2864.8	3	954.9	5	573	7	409.3
30	1909.9	3 30	818.5	5 30	520.9	7 30	382
	1432.4	4	716.2	6	447.5	8	358.1

OTE.—If chords of less length are used, radius will be proportional thereto.

To Ascertain Radius of Curve in Inches for Scale, in Feet per Inch.

›ivide radius of curve in feet by scale of feet per inch.

To Compute Required Weight of Rail.

ULE.—Multiply extreme load upon one driving-wheel in lbs. by .005, product will give weight of rail in lbs. per yard.

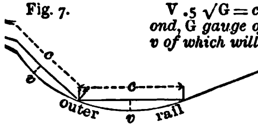
To Compute Radius of Curve and Wheel Base.

B G = R. $\frac{R}{9\,G} = B$. B *representing maximum rigid wheel base of cars, and* G *ge of way, both in feet.*

To Determine Elevation of Outer Rail.

For any Radius or Construction of Curve with Straight.—Fig. 7.

Fig. 7.



$V\,.5\,\sqrt{G} = c$. V *representing speed of train in feet per second,* G *gauge of rails in feet, and* c *length of chord, versed sine* v *of which will give at its centre the elevation required.*

Thus, determine chord *c*, align it on inner side of rail, and distance of rail from it at centre of its length will give elevation required, whatever the radius of rail.

or Curves. $\frac{[.782\,V^2\,(N\,D\,W)] - 4\,P\,R}{N\,D\,R} = E$; Or, $W\frac{V^2}{1.25\,R} = E$. D *representing* *neter of wheels,* W *width of gauge,* P *lateral play between flange and rail, and adius of curve, all in feet,* $1 \div N$ *ratio of inclination of tire.* V *velocity of train in s per hour, and* E *elevation of outer rail in ins.* (*Molesworth.*)

$\frac{C\,(d+l)}{2\,R}$ = *resistance due to curve, and* W *representing weight of body, both in* C *coefficient of friction of wheels upon rails* = .1 *to* .27, *according to condition of ther,* d *distance of rails apart,* l *length of rigid wheel base, and* R *radius of curve, n feet.* (*Morrison.*)

LUSTRATION.—Assume weight of locomotive 30 tons, radius of curve 1000 feet, nce of rails apart 4 feet 8.75 ins., length of base 10 feet, and rails, dry, C = 1.

$$\frac{30 \times 2240 \times 1 \times (4.73 + 10)}{2 \times 1000} = 494.93 \text{ lbs.}$$

Compute Resistance due to Gravity up clination.

$$\frac{2240}{\text{gradient}} = \text{lbs. per ton of train.}$$

e per Mile, and Resistance to Gravity, in Ton.

lent of 1 inch..	20	25	30	35	40	45	50	60	70	8c
in feet........	264	211	176	151	132	117	106	88	75	66
tance.........	112	89.6	74.7	64	56	50	44.8	37.3	32	28

To Compute Load which a Locomotive will Dra an Inclination.

$T \div \overline{r + r'} - W = L$. T *representing tractive power of locomotive in lbs sistance due to gravity, and r' resistance due to assumed velocity of train in ton,* W *weight of locomotive and tender, and* L *load locomotive can draw, in t clusive of its own weight and tender.*

Coefficients of Traction of Locomotives.—Railroads in good order, etc., 4 to in ordinary condition, 8 lbs.

In coupled engines adhesion is due to load upon wheels coupled to d

To Compute Traction, Retraction, and Adhesive P of a Locomotive or Train.

When upon a Level. $a\,s\,P \div D = T$. *a representing area of one cylin sq. ins., s stroke of piston and* D *diameter of driving-wheels, both in feet,* P *pressure of steam in lbs. per sq. inch, and* T *traction, in lbs.*

When upon an Inclination. $a\,s\,P \div D - r\,w\,h = T$. *r representing res per ton, w weight of locomotive upon driving-wheels, in tons, h height of rise per* 100 *of road, and* $R = r\,w\,h$ = *retraction, in lbs.*

$C\,w\,b \div 100 = A$. *b representing base of inclination in feet per* 100 *of road*

$C\,w = A$. C = *coefficient in lbs. per ton, and* A *adhesion, in lbs.*

When Velocity of a Train is considered.

When upon a Level, $W\,(C + \sqrt{V}) = R$. *When upon an Inclin* $W\,(r\,h + C + \sqrt{V}) = R$. V *representing velocity of train in miles per hou*

ILLUSTRATION.—A train weighing 200 tons is to be driven up a grade of 52 per mile, with a velocity of 16 miles per hour; required the retractive power

52.8 per mile = 1 in 100 feet = r = 22.4 lbs. C = 5.

$200\,(22.4 \times 1 + 5 + \sqrt{16}) = 200 \times \overline{22.4 + 9} = 6280$ *lbs.*

Velocity of Trains.

Miles per hour	10	15	20	30	40	50	60
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Resistance upon straight line per ton	8.5	9.25	10.25	13.25	17.25	22.5	29
Do., with sharp curves and strong wind*	13	14	15.5	20	26	34	43.5

* Equal to 50 per cent. added to resistance upon a straight line.

Friction of locomotive engines is about 9 per cent., or 2 lbs. per ton of weig

Case-hardening of wheel-tires reduces their friction from 14 to .08 part of

To Compute Maximum Load that can be drawn by Engine, up the Maximum Grade that it can Att Weight and Grade being given. (*Maj. McClellan, U.S.A*

$\frac{.2\,A}{.4242\,G + 8} = L$, and $\frac{.2\,A - 8\,L}{.4242\,L} = G$. A *representing adhesive weight of* *lbs.,* G *grade in feet per mile, and* L *load, in tons.*

L.—When rails are out of order, and slippery, etc., for .2 A, put .143 A

h an engine of 4 drivers, put .6 as weight resting upon drivers; entire weight rests upon them.

—An engine weighing 30 tons has 6 drivers; what are the maxi upon a level, and upon a grade of 250 feet, and what is its load?

= 1595.4 tons upon a level. $\frac{.2 \times 2240 \times 30}{.4242 \times 250 + 8} = \frac{134}{}$

$\frac{.2 \times 2240 \times 30 - 8 \times 117.8}{.4242 \times 117.8} = \frac{12\,497}{49.97} =$

pared with one of 6 whee

OPERATION OF LOCOMOTIVES. (*O. Chanute, Am. Soc. C. E.*)

Adhesion.

esion of a locomotive is friction of its driving-wheels upon the rails, g with condition of the surface, and must exceed traction of the engine hem, otherwise the wheels will slip.

rovements heretofore made in the construction of locomotives and have gradually increased the proportion which the adhesion bears to istent weight upon the driving-wheels.

irst accurate experiments were those of Mr. Wood upon the early English ilways. He deduced the adhesion to be as follows:

on perfectly dry rails........................ .14 of weight on drivers.
" damp or muddy rails...................... .08 " " " "
" very greasy rails......................... .04 " " " "

38, B. H. Latrobe indicated .13 as a safe working adhesion, while modern an practice assumes about .2 of weight as maximum, and .11 as a minimum, perhaps in some mountainous regions, subject to mists. Thus, on the Sœmline, adhesion is generally .16, and between Pontedecimo and Busalla, in never exceeds .12 in open cuttings, or .1 in tunnels.

isive experiments made upon French railways, 1862–67, by Messrs. Vuilleiebhard, and Dieudonné gave following coefficients in actual working: *dry* , extreme, .105 to .2; *damp*, .132 to .139; *wet*, .078 to .164; *light rain*, .09; *rain*, .109 to .2, *mean*, .13; *rain and fog*, .115 to .14; *heavy rain*, 16.

rially better results are obtained in United States, partly, perhaps, in cone of greater dryness of the weather, and certainly because of the American of construction and equalizing the weight between the drivers, and of mak- locomotive so flexible as to adapt itself to inequalities in the track.

rn engines in America can safely be relied upon to operate up to an adhesion .222 in summer and .2 in winter, of weight upon the driving wheels.

these data the following tables have been computed:

icients of Adhesion upon Driving Wheels per Ton.

ion of Rails.	European Practice.		American Practice.		Condition of Rails.	European Practice.		American Practice.	
	C.	Lbs.	C.	Lbs.		C.	Lbs.	C.	Lbs.
ry dry.....	.3	670	.33	667	In misty weather.	.015	350	.2	400
ry wet.....	.27	600	.25	500	In frost and snow.	.09	200	.16	333
y working..	.2	450	.222	444					

iesion of Locomotives, in Lbs. (.222 *in Summer and* .2 *in Winter*).

Locomotive.	No. of Drivers.	Weight. Locomotive.	Weight. On Drivers.	Adhesion. Summer.	Adhesion. Winter.
		Lbs.	Lbs.	Lbs.	Lbs.
in..........	4 wheels coupled....	64000	42000	9 [illegible]	8 [illegible]
eeled.......	6 " connected..	78000	58000	1[illegible]	
....	6 " " ..	88000	72000	1[illegible]	
lation......	8 " " ..	100000	88000	[illegible]	
vitching....	6 " " ..	68000	68000	1[illegible]	
"	4 " " ..	48000	48000	10	

Tractive Power.

tion of a locomotive is the horizontal resultant on the t e of the steam, as applied in the cylinders.

L ÷ W = T. D *representing diameter of cylinder*, L *length of st*
of driving wheels, all in ins., P *mean pressure in cylinder*, in
d T *tractive force on rails, in lbs.*

RATION.—*Assume* a locomotive, cylinders 18 ins. in diam., 22 in. *ins. in diam.*, and *average* steam pressure in cylinders 50 lbs. per

Then $18 \times 18 \times 50 \times 22 \div 68 = 5241$ lbs.

$$20^2 \div 171 + 8 = 10.3 \textit{ lbs. per ton of train.}$$

This formula, however, is empirical. It gives results which are too freight trains at moderate speeds, and too small for passenger trains at hi

Engineers are not agreed as to exact measure and value of each of th of train resistances, but following approximations are sufficient for pract

Analysis of Train Resistances.

Resistance of trains to traction may be divided into four prin ments: 1st. Grades; 2d. Curves; 3d. Wheel friction; 4th. Atmosp

1st. *Grades.* — Gradients generally oppose largest element of r to trains. Their influence is entirely independent of speed. Th ure of this resistance is equal to weight of train multiplied by ra clination or per cent. of grade. Thus, a gradient of .5 per 100 f feet per mile) offers a resistance of $\frac{5 \times 2240}{10 \times 100} = 11.2$ lbs. per ton, o per 2000 lbs., which is to be multiplied by weight in tons of entire

Following table shows resistance, due to gravity alone, for the most usu in lbs. per ton of train:

1st. *Resistance due to Grades.*

Rate per 100 feet.........	.1	.2	.3	.4	.5	.6	.7
Lbs. per ton of 2240 lbs...	2.24	4.48	6.72	8.96	11.2	13.44	15.6
Rate per mile............	5	11	16	21	26	32	37
Lbs. per ton of 2000 lbs...	2	4	6	8	10	12	14
Rate per 100 feet.........	.9	1	1.1	1.2	1.3	1.4	1.5
Lbs. per ton of 2240 lbs...	20.16	22.4	24.64	26.88	29.12	31.36	33.6
Rate per mile............	47	53	58	63	68	74	79
Lbs. per ton of 2000 lbs...	18	20	22	24	26	28	30

2d. *Curves.*—Recent European formula is that given by Baron von

ıewhat reduced when curve coincides with that for which wheels a
.lly about 3°), and when train runs over it, at precise speed for which
levated, an allowance of .5 lb. per ton per degree is found to give good
:tice.

2d. *Resistance on Curves.*

'om above estimate of curve resistance that, in order to have the same
a curve as on a straight line, the gradient should be diminished by
:t of each degree of curve. Thus a 3° curve requires an easing of the
ıer 100 feet, a 10° curve an easing of .3 per 100, etc.

'er, need only be done upon the *limiting* gradients, and when sum of
ve resistances exceeds resistance which has been assumed as limiting

3d. *Resistance due to Wheel Friction.*

.ers are not agreed whether friction of wheels increases simply with
they carry, but also in some ratio with the speed. Originally as-
onstant at 8 lbs. per ton, improvements in condition of track (steel
1 in construction and lubrication of rolling-stock have reduced it to
per ton for well-oiled trains. Under ordinary circumstances, in sum-
e safe to estimate it at 5 lbs. per ton on first-class tracks, and 6 lbs.
ir tracks. It may run up to 7 or 8 lbs. per ton on bad tracks (iron
ıer, and all these amounts should be increased from 25 to 50 per cent.
es in winter, to allow for inferior lubrication.

4th. *Resistance due to Atmosphere.*

c resistance to trains, complicated as it is by the wind which may be
s not been accurately ascertained by experiment. It consists of—
stance of first car of train, which is presumably equal to its exposed
:t, multiplied by air pressure due to speed.

sistance of each subsequent car. This varies with distance they are
, and so shield each other from end air pressure due to speed.

of air against sides of each car depending upon the speed. This is
mall that it may be neglected altogether.

luc to prevailing wind, which modifies above three items of resistance.
retards the train, a rear wind aids it, while a side wind increases re-
essing flanges of wheels against one rail, and, in consequence of curves,
ssume all of these positions to same wind.

eriments on Erie Railway seem to indicate that in a dead calm re-
st car of a *freight train* may be assumed at an exposed surface of 63
tiplied by air pressure due to speed, and that each subsequent car may
ɔ offer a resistance of 20 per cent. of that of first car, while in a *pas-*
irst car may be assumed at an area of 90 sq. feet,† multiplied by air
to speed, and that each subsequent car adds an increment equal to 40
of first car, in consequence of greater distance they are coupled apart.

nce is, of course, entirely independent of cars being loaded or empty.
has been found that an allowance of 1.5 to 2 lbs. per ton of weight of
ı covers atmospheric resistance, except in very high winds.

ınce of complexity of elements above enumerated, exact formulas can-
be now given for train resistances, but following, if applied with judg-
dified to fit circumstances), will be found to give fairly accurate results
They are for standard gauge, and in making them, curve resistance has
l at .5 lb. per degree, wheel friction at 5 lbs., exposed end area of first
'eet for passenger cars and 63 feet for freight cars, and increment for
rs at .4 for passenger trains and .2 for freight trains.

;er Train. $W\left(G+\frac{C^\circ}{2}+5\right)+\left(1+\frac{n-1}{2.5}\right)90\,P=R.$

Train. $W\left(G+\frac{C^\circ}{2}+5\right)+\left(1+\frac{n-1}{5}\right)63\,P=R.$

ıan area of car, which generally measures about 71 sq. feet; but part is t.
eing convex, as wheels, bolts, etc., offer less resistance than a flat plane.
l area of passenger cars greater than that of freight cars, but in consequen
end forms a hood in nature of a concave surface, and so opposes greater resi

weight of train, without engine, in tons (2000 lbs.), G
(2000 lbs.; see table, page 683), C° curve in degrees, n n
pressure per sq. foot due to speed, to which an allowance mus
if existing, R resistance of train, and 5, wheel friction, both in lbs.

ILLUSTRATION 1.—Assume a passenger train of 5 cars, weighing 136 to ascending a grade .5 per 100 (26.4 feet per mile), with curves of 4°, at miles per hour (for which the pressure is 18 lbs. per sq. foot), resistanc

$$136\,(10+2+5)+\left(1+\frac{4}{2.5}\right)(90\times 18)=6524$$ *lbs., of which* 2312 *lb* *grade, curve, and wheels, and* 4212 *lbs. to atmospheric resistance.*

2.—Assume a freight train of 31 cars, weighing 620 tons (2000 lbs.), tu of 3°, up a grade of 52.8 feet per mile (1 foot per 100), at a speed of 21 m (pressure 2 lbs. per sq. foot), resistance will be:

$$620\,(20+1.5+5)+\left(1+\frac{30}{5}\right)(63\times 2)=17\,312$$ *lbs.*, requiring a "Co engine to haul it, allowance being made for possible winds, etc.

Assume conversely, it is desired to know how many tons an Amer with an adhesion of 10 650 lbs., will draw up a grade of .9 per 100 (47 fe with curves of 4°, assuming atmospheric resistance between 1.5 to 2 lb train.

Resistance from grade $.9\times 2000\div 100$ .... = 18 *lbs.*
" " curve $4\div 2$ .... = 2 "
" " wheel friction 5, atmosphere 2..... = 7 "

Hence, $10\,650\div 27=395$ *tons, or about* 20 *cars*, and in winter same haul $9600\div 27=355$ *tons* (2000 lbs.), *or about* 18 *cars.*

Following table approximates to best modern practice. For *freight tr* aggregate resistance, in lbs. per ton (2000 lbs.), for various grades and using it, it is sufficient to divide the adhesion in lbs. of locomotive use found in table, in order to obtain number of tons of train that it wil dinary speeds on gradient and curve selected. Of course, if grade has l for curves, only number found in first column (for straight lines) is t computing tons of train on limiting gradient.

Approximate Freight-train Resistances

Gauge 4 feet 8.5 ins.

In Lbs. per 2000 lbs. at Ordinary Speeds.

Curve Resistance assumed at .5 lbs. per °, Wheel Friction at 5 lbs., Atm sistance at 2 lbs. per Ton.

Grade. Per Cent.	Grade. Per Mile.	Straight.	Curve. 1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Level.	Feet.	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13
.1	5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
.2	11	11	11.5	12	12.5	13	13.5	14	14.5	15	15.5	16	16.5	17
.3	16	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5	18	18.5	19
.4	21	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5	20	20.5	21
.5	26	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5	23
.6	32	19	19.5	20	20.5	21	21.5	22	22.5	23	23.5	24	24.5	25
	37	21	21.5	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5	27
		23	23.5	24	24.5	25	25.5	26	26.5	27	27.5	28	28.5	29
		25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31
		7	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33
		[illegible]	29.5	30	30.5	31	31.5	32	32.5	33	33.5	34	34.5	35
		[illegible]	31.5	32	32.5	33	33.5	34	34.5	35	35.5	36	36.5	37
			33.5	34	34.3	35	35.5	36	36.5	37	37.5	38	38.5	39
				[illegible]	36.5	37	37.5	38	38.5	39	39.5	40	40.5	41
					[illegible]	39	39.5	40	40.5	41	41.5	42	42.5	43
						41	41.5	42	42.5	43	43.5	44	44.5	45

"Mogul" engine to have an adhesion
rade of 74 feet per mile, combined w
$\div 39.5 = 405$ tons (2000 lbs.).

nce, *To Compute Adhesion on a Given Grade and Curve, having Weight ain.*

LE.—Multiply tabular number by weight of train in tons (2000 lbs.), roduct will give adhesion, in lbs.

MPLE.—Assume preceding elements. Then $39.5 \times 405 = 16\,000$ *lbs.*

E.—A "Consolidation" engine, by its superior adhesion (19 550 lbs.) would p a like grade and curve 495 tons.

Memoranda on English Railways.

Regulations (Board of Trade).

-iron girders to have a breaking weight = 3 times permanent load, added to s moving load.
ught-iron bridges not to be strained to more than 5 tons per sq. inch.
imum distance of standing work from outer edge of rail at level of carriage 3.5 feet in England and 4 feet in Ireland.
imum distance between lines of railway, 6 feet.

ions.—Minimum width of platform, 6 feet, and 12 at important stations. ium distance of columns from edge of platform, 6 feet. Steepest gradient for is, 1 in 260. Ends of platforms to be ramped (not *stepped*). Signals and dis-ignals in both directions.

riages.—Minimum space per passenger 20 cube feet. Minimum area of glass assenger, 60 sq. ins. Minimum width of seats, 15 ins. Minimum breadth of er passenger, 18 ins. Minimum number of lamps per carriage, 2.

uirements.—Joints of rails to be fished. Chairs to be secured by *iron* spikes. bolts to be used at the joints of flat-bottomed rails.

Construction.	Narrow. Feet.	Ins.	Broad. Feet.	Ins.
'idth, single line	18		24	6
" double line	30		38	
" top of ballast, single line	13	6	15	6
" " " double line	24	6	29	

e of cuttings from centre, 1 in 30. Width of land beyond bottom of slope, feet. Ditch with slopes, 1 foot at bottom, 1 to 1. Quick mound, 18 ins. in . Post and rail-fence posts, 7 feet 6 ins. × 6 ins. × 3.5 ins., 9 feet apart, 3 feet und. Intermediate posts, 5 feet 6 ins. × 4 ins. × 1.5 ins., 3 feet apart. Rails × 1.5 ins.

Parliamentary Regulations for Crossing Roads.

	Turnpike Road. Feet.	Ins.	Public Road. Feet.	Ins.	Occupation Road. Feet.	Ins.
width of under bridge, or approach	35	—	25	—	12	—
height of under bridge for a width of 12 ft.	16	—	—	—	—	—
" " " " 10 "	—	—	15	—	—	—
" " " " 9 "	—	—	—		14	—
" " at springing	12	—				—
bridge, height of parapets	4	—				
aches, inclination	1 in 30					
" height of fencing	3	—				

nits of Deviation.—In towns, 10 yards each side of ry, 100 yards, or 5 chains nearly.

el.—In towns, 2 feet. In country, 5 feet.

dient.—*Gradients flatter* than 1 in 100, deviation 10 *Do., steeper, 3 feet* per mile.

.—Curves upwards of .5 a mile radius, may be sharpen *Curves of less than* .5 mile radius may not be sharpene

ROADS, STREETS, AND PAVEMENTS.

Classification of Roads.

1. Earth. 2. Corduroy. 3. Plank. 4. Gravel. 5. Broken stone (Macadam). 6. Stone sub-pavement with surface of broken stone (Telford). 7. Stone sub-pavement with surface of broken stone and gravel, or gravel alone. 8. Rubble stone bottom with surface of broken stone or gravel, or both. 9. Concrete bottom with surface of broken stone or gravel, or both.

Grade of Roads.

Limit of practicable grade varies with character of road and friction of vehicle. For best carriages on best roads, limit is 1 in 35, or 15 feet in a mile.

Maximum grade of a turnpike road is 1 in 30 feet. An ascent is easier for draught if taken in alternate ascents and levels, than in one continuous rise, although the ascents may be steeper than in a uniform grade.

Ordinary angle of repose is 1 in 40 if roads are bad, and 1 in 30, to 1 in [illegible]

When roads have a greater grade than 1 in 35, time is lost in descending, in order to avoid unsafe speed. Grade of a road should be less than its *angle of repose.* Minimum grade of a road to secure effective drainage should be 1 in 80. In France it is 1 in 125.

In construction of roads the advantage of a level road over that of an inclined one, in reduction of labor, is superior to cost of an increased length of road in the avoiding of a hill.

Alpine roads over the Simplon Pass average 1 in 17 on Swiss side, 1 in [illegible] on Italian side, and in one instance 1 in 13.

In deciding upon a grade, the motive power available of ascent and available of waste of power in descending are to be first considered.

When traffic is heavier in one direction than the other, the grade in ascent of lighter traffic may be greatest.

When axis of a road is upon side of a hill, and road is made in part by excavation and by embankment, the side surface should be cut into steps in order to afford a secure footing to embankment, and in extreme cases sustaining walls should be erected.

Construction.

Estimate of Labor in Construction of Roads. (M. Ancelin.)

A day's work of 10 hours of an average laborer is estimated as follows:

In Cube Yards.

Work.	Ordinary Earth.	Loose Earth.	Mud.	Clay and Earth.	Gravel.	[illegible]
Picking and digging......	18 to 23	16	—	9	7 to 11	14
Excavation and pitching 6 to 12 feet...........	8 to 12	8	7 to 16	4	—	12
Loading in barrows.......	22	—	8	—	19	-
Wheeling in barrows per [illegible] feet..............	20 to 33	—	—	—	24 to 28	-
[illegible]ing in carts..........	16 to 48	—	—	—	17 to 27	-
[illegible]ding and levelling...	44 to 88	—	25	—	30 to 80	-

[illegible] of pitching from a shovel is one third of that of digging.

[illegible] All ditches should lead to a natural water-course, and their [illegible] should be 1 in 125.

[illegible] elevations in surface of a roadway involve a material [illegible] [illegible]tion is 1 inch, under a wheel 4 feet in diameter, to [illegible] be surmounted, and, as a consequence, one seventh of [illegible]

An unyielding foundation and surface are indispensable for a perfect roadway.

Earth in embankment occupies an average of one tenth less space than in natural ınk, and rock about one third more.

Ruts.—Surface of a roadway should be maintained as intact as prac- :able, as the rutting of it not only tends to a rapid destruction of it, but volves increased traction.

The general practice of rutting a road displays a degree of ignorance of ;ysical laws and mechanical effects that is as inexplicable as it is injurious d expensive.

On compressible roadways, as earth, sand, etc., resistance of a wheel decreases as adth of tire increases.

Depressing of axles at their ends increases friction. Long and pliant springs de- ase effect of shock in passing over obstacles in a very great degree.

Transverse Section.—Best profile of section of roadway is held to be one :med by two inclined planes meeting in centre of road and slightly unded off at point of junction.

Roads having a rough surface or of broken stone should have a rise of ın 24, equal to a rise on crown of 6 ins., and on a smooth surface, as a ock-stone or wood pavement, the rise may be reduced to 1 in 48.

On roads, when longitudinal inclination is great, the rise of transverse :tion should be increased, in order that surface water may more readily n off to sides of roadway, instead of down its length, and consequently llying it.

Stone Breaking. A steam stone-breaking machine will break a cube yard stone into cubes of 1.5 ins. side, at rate of 1 to 1.5 IP per hour.

Macadamized Roads.

In construction of a Macadamized road, the stones (road metal) used ould be hard and rough, and cubical in form, the longest diameter of which ceed 2.5 ins., but when they are very hard this may be reduced to 1.25 d 1.5 ins.

The best stones are such as are difficult of fracture, as basaltic and trap, d especially when they are combined with hornblende. Flint and sili- ous stone are rendered unfit for use by being too brittle. Light granites : objectionable, in consequence of their being brittle and liable to disinte- ition; dark granites, possessing hornblende, are less objectionable. Lime- nes, sandstones, and slate are too weak and friable.

Dimensions of a hammer for breaking the stone should be, head 6 ins. in gth, weighing 1 lb., handle 18 ins. in length; and an average laborer can ak from 1.5 to 2 cube yards per day.

tones broken up in this manner have a volume twice as grea inal form. 100 cube feet of rock will make 190 of 1.5 ins of 2 ins., and 170 of 2.5 ins.

ton of hard metal has a volume of 1.185 cube yards.

onstruction of a Roadway.—Excavate and level to a depth t lay a "bottom" 12 ins. deep of brick or stone spalls or ch ld concrete, etc., roll down to 9 ins, then add a layer of coars ll ballast *5 ins. deep, roll* down to 3 ins., and then metal in 2 f *3 ins., laid at an interval,* enabling first layer to be fully co e *second is laid* on and rolled to a depth of 4 ins.; a surface o 5 *inch of sharp sand* should be laid over last layer of metal a th *a free supply of water.*

depth at sides of road to 4, 5, and 7 inches to centre, and set ı broadest edge, free from irregularities in their upper surface, an terstices filled with stone spalls or chips, firmly wedged in.

Centre portion of road to be metalled first to a depth of 4 ins. after being used for a brief period, 2 ins. more are to be added, surface to be covered, "blinded," with clean gravel 1.5 ins. in dep

Telford assigned a load not to exceed 1 ton upon each wheel o with a tire 4 ins. in breadth.

Gravel or Earth Roads.

In construction of a gravel or earth road, selection should be ma clean round gravel that will not pack, and sharp gravel intern earth or clay, that will bind or compact when submitted to the traffic or a roll.

Surface of an ordinary gravel roadway should be excavated to from 8 to 12 ins. for full width of road, the surface of excavation c to that of road to be constructed.

The gravel should then be spread in layers, and each layer con the gradual pressure due to travel over it, or by a roller, the weig creasing with each layer. One of 6 tons will suffice for limit of

If gravel is dry and will not readily pack, it should be wet, with a binding material, or covered with a thin layer of it, as clay

In rolling, the sides of road should be first rolled, in order to gravel, when the centre is being rolled, from spreading at the side.

To re-form a mile of gravel or earth road, 30 feet in width betwe material cast up from sides, there will be required 1640 hours' lab and 20 of a double team.

Corduroy Roads.

A Corduroy road is one in which timber logs are laid transversely t

Asphalt.

sphalt is a bituminous limestone, and is synonymous with bitumen; it sists of from 90 to 94 per cent. of carbonate of lime and 6 to 10 per cent. itumen.

. forming a pavement the powder is heated to from 212° to 250°, and its par-s caused to adhere by pressure, or it is applied as a liquid asphalt or asphaltic tic, which is thus manufactured. The powder is heated with from 5 to 8 per . of free bitumen for a flux, and the mixture when melted is run into molds. e remelted, additional bitumen must be mixed with it, without which it would become soft.

or paving 60 per cent. of sand or gravel must be mixed with it. No chemical n takes place between the mastic and the sand or gravel, but cohesion is so plete that gravel will fracture with the mastic, and the admixture increases the stance of the mass to heat of the sun. The roadway should have a convexity 1 of its breadth.

rtificial Asphalt.—Heated limestone and gas tar, when mixed, possess e of the proportions of alphalt mastic, but it is very inferior for the poses of a pavement.

o repair surface of roadway, dissolve bitumen 1 part in 3 of pitch oil or in oil, apply 10 oz. of mixture over each sq. yard of roadway, sprinkle on lbs. of asphalt powder, and then cover surface with sand.

Wood Pavement.

lose-grained and hard woods only are suitable, such as oak, elm, ash, ch, and yellow pine, and they should be laid on a foundation of concrete.

Block Stone Pavement.

aving-blocks, as the Belgian, etc., where crest of street or area of pave-nt does not exceed 1 inch in 7.5 feet, should taper slightly toward the , and the joints be well filled, "blinded," with gravel. The common ctice of tapering them downward is erroneous.

he foundation or bottoming of a stone pavement for street travel should sist either of hydraulic concrete or rubble masonry in hydraulic mortar. practice in this country of setting the stones in sand alone is at variance h endurance and ultimate economy, but when resorted to, there should be ed of 12 ins. of gravel, rammed in three layers, covered with an inch of d. Granite or Trap blocks should be 4 × 9 × 12 ins.

Rubble Stone Pavement.

owlders or Beach stone of irregular volumes and forms, set in a bed of l, involves great resistance to vehicles and frequent repairs; it is wholly ariance with requirements of heavy traffic or city use.

Concrete Roads.

ncrete roads are constructed of broken stones (road metal) 4 volumes, sharp sand 1.25 to .33 volumes, and hydraulic cement 1 volume. The is laid down in a layer of 3 or 4 ins. in depth, and left to harden during riod of 3 days, when a second and like layer is laid on and then left to harden for a period of from 10 to 20 days, perature and moisture of the weather.

Roads. (*Molesworth.*)

dinary turnpike roads.—30 feet wide, centre 6 ins. higher t from centre, .5 inch below centre; 9 feet from centre, 2 e; 15 feet from centre, 6 ins. below centre.

ot-paths—6 feet wide, inclined 1 inch towards road, of fine d quarry chippings, 3 ins. thick.

ss-roads—20 feet wide. *Foot-paths*—5 feet.

e drains—3 feet below surface of road.

ad material—bottom layer gravel, burned clay or chalk, 8 yer, broken granite not larger than 1.5 cube ins., 6 ins. deep.

Metalled Roads should be swept wet.

Rolling.—Steam rolls are most effective and economical. 1000 sq. yards ling will require 24 hours' rolling at 1.5 miles per hour. A roller of 15 to will roll 1000 sq. yards of Telford or Macadam pavement in from 30 to 4 a speed of 1.5 miles per hour, equal .675 and .9 ton mile per sq. yard.

Sprinkling.—60 cube feet of water with one cart will cover 850 sq. y cube feet per day will cover 1000 sq. yards; ordinarily two sprinklings are

Granite Pavement.—The wear of granite pavement of London Bridge wa per year, and from an average of several streets in London, the wear per 1 per foot of width per day is equal to one sixteenth of an inch per year.

Sweeping and Watering of granite pavement and Macadam road, for e and under alike conditions in every respect, costs as 1 for former to 7 of

By men, with cart, horse, and driver, costs 3.25 times more than by a one of which will sweep 16 000 sq. yards of street per period of 6 hours.

Asphalt Pavement. — Average cost per sq. yard in London: foundation, surface, $3.25; cost of maintenance per sq. yard per year, 40 cents. W from .2 to .42 near curb, and .17 to .34 inch on general surface per year.

Washing.—Surface cleaning of stone or asphalt pavement by a jet can b at from 1 to 2 gallons per sq. yard.

Wood Pavement.—Wear of wood pavement in London, per 100 vehicle per foot of width, .083 inch per year.

Macadamized Roads. — Annual cost of maintenance of several such London was 62 cents per sq. yard.

Block Stone Pavement.—Stones should be set with their tapered or least wards, with surface joints of 1 inch.

Fascines, when used, should be in two layers, laid crosswise to each picketed down.

Bituminous road may be made by breaking up asphalt, laying it 2 i covering with coal tar, and ramming it with a heavy beetle. To repair nous surface, dissolve one part of bitumen (mineral tar) in three of pitch oi oil. spread .625 of a lb. of solution over each sq. yard of road. sprinkle 2

SEWERS.

rs are the courses from a series of locations, and are classed as , Sewers, and Culverts.

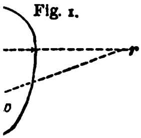
ins are small courses, from one or more points leading to a sewer.

erts are courses that receive the discharge of sewers.

test fall of rain is 2 ins. per hour = 54 308.6 galls. per acre.

nation of sewers should not be less than 1 foot in 240, and for or short lateral service it should be 1 inch in 5 feet.

Fig. 1.



Circular. $55\sqrt{x\ 2\ f} = v$, and $v\ a = V$.

Egg. $\frac{D}{3} = w$, $\frac{2\ D}{3} = w'$, and $D = r$. *x representing area of sewer ÷ wetted perimeter, f inclination of sewer per mile, and v velocity of flow of contents in feet per minute; a area of flow, in sq. feet, V volume of discharge, in cube feet per minute; D height of sewer, w and w' width at bottom and top, and r radius of sides, in feet.*

For diameter of sewer exceeding 6 feet. (*T. Hawksley.*)

$D - \frac{1}{9} = w'$. *D diameter of a circular sewer of area required.*

Elliptic.—Top and bottom internal should be of equal diameters. Diameter .66 depth of culvert; intersections of top and bottom circles form centres for striking courses connecting top and bottom circles.

Pipes or Small Sewers.—Height of section = 1; diameter = .66; of invert = .33, and radius of sides = 1.

lverts less than 6 feet internal depth, brickwork should be 9 ins. thick; ey are above 6 feet and less than 9 feet, it should be 14 ins. thick. ameter of top arch = 1, diameter of inverted arch = .5, and total : sum of the two diameters, or 1.5; then radius of the arcs which are ial to the top, and inverted, will be 1.5.

this any two of the elements can be deduced, one being known.

Drainage of Lands by Pipes.

Soils.	Depth of Pipes.	Distance apart.	Soils.	Depth of Pipes.	Distance apart.
	Ft. Ins.	Feet.		Ft. Ins.	Feet.
ravel sand	4 6	60	Loam with gravel ...	3 3	27
nd with gravel	4	50	Sandy loam.........	3 9	40
m	3 6	33	Soft clay...........	2 9	21
ith clay.......	3 2	21	Stiff clay...........	2 6	15

num Velocity and Grade of Sewers and Drains in Cities. (*Wicksteed.*)

Vel. per Minute.	Grade, 1 in	Grade per Mile.	Diam.	Vel. per Minute.	Grade, 1 in	Grade per Mile.	Diam.	Vel. per Min	ade
Feet.		Feet.	Ins.	Feet.		Feet.	Ins.	Fe	
240	36	146.7	15	180	244	21.6	42	18	
220	65	81.2	18	180	294	18	48	18	
220	87	60.7	24	180	392	13.5	54	18c	
210	119	44.4	30	180	490	10.8	60	18c	
190	175	30.2	36	180	588	9			

of Sewers or Pipes.—An area of 20 acres, miles, etc. *times capacity of pipes for one acre, mile, etc.*, as the d.. *res, etc., will not flow into the main simultaneously* w.. *etc.* *Ordinarily in this country an area of sewer or* pi.. *a rainfall of 1 inch per hour* (3630 cube feet per acre) is

Sewage.—The excreta per annum of 100 individuals of both sexes and all ages is estimated at 7250 lbs. solid matter and 94 700 fluid, equal to [illegible] lbs. *per capita*, and in volume 16 cube feet, to which is to be added the volume of water used for domestic purposes. A velocity of flow of from 2½ to 3 feet per second will discharge a sewer of its sewage matter and prevent deposits. The minimum velocity should not be less than 1.3 feet per second.

Surface from which Circular Sewers with proper Curves will discharge Water equal in Volume to One Inch in Depth per Hour, including City Drainage. (*John Roe.*)

Inclination in Feet.	Diameter of Sewers in Feet. 2	2.5	3	4	5	6	7	8
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
None	38.75	67.25	120	277	570	1020	1725	[illegible]
1 in 480	48	75	135	308	630	1117	1925	[illegible]
1 in 240	50	87	155	355	735	1318	2225	[illegible]
1 in 160	63	113	203	460	950	1692	2875	[illegible]
1 in 120	78	143	257	590	1200	2180	3700	[illegible]
1 in 80	90	165	295	570	1388	2486	4225	[illegible]
1 in 60	125	182	318	730	1500	2675	4550	[illegible]

Surface of a Town from which small Circular Drains will discharge Water equal in Volume to Two Inches in Depth per Hour. (*John Roe.*)

Inclination. Fall of 1 Inch.	Diameter of Drain in Ins. 3	4		6	7	8	Inclination. Fall of 1 Inch.	Diameter of Drain in Ins. 9	12	15	[illegible]
Acres.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Acres.	Feet.	Feet.	Feet.	Feet.
.125	120	—		—	—	—	2.1	120	—	—	—
.25	20	120		—	—	—	2.5	80	—	—	—
.4375	—	40		—	—	—	2.75	60	—	—	—
.5	—	30	80	—	—	—	4.5	—	120	—	—
.6	—	20	60	—	—	—	5.3	—	80	—	—
1	—	—	20	60	—	—	5.8	—	60	240	—
1.2	—	—		40	20	—	7.8	—	—	120	—
1.5	—	—		20	60	120	9	—	—	80	—
1.8	—	—		—	—	80	10	—	—	60	240
2.1	—	—		—	—	60	17	—	—	—	120

Dimensions, Areas, and Volume of Material per Lineal Foot of Egg-shaped Sewers of different Dimensions.

Depth.	Internal Dimensions. Diam. of Top Arch.	Diam. of Invert.	Area.	Volume of Brick-work. 4.5 Ins. thick.	9 Ins. thick.	13.5 Ins. thick.
Feet.	Feet.	Feet.	Sq. Feet.	Cube Feet.	Cube Feet.	Cube Feet.
2.25	1.5	.75	2.53	2.81	—	—
3	2	1	4.5	3.56	—	—
3.75	2.5	1.25	7.03	4.31	9.56	—
4.5	3	1.5	10.12	5.06	10.87	—
5.5	3.5	1.75	13.78	5.81	12.75	—
6	4	2	18	6.56	14.25	—
6.75	4.5	2.25	22.78	7.31	15.75	24.75
7.5	5	2.5	28.12	—	17.06	27
[illegible]5	5.5	2.75	34.03	—	18	28.41
[illegible]	6	3	40.5	—	19.69	30.94

[illegible] = product of mean diameter × height.

have a uniform thickness and be uniformly [illegible]
[illegible]rnally.
[illegible] be thicker than those of stone-clay.

STABILITY.

[TY, *Strength*, and *Stiffness* are necessary to permanence of a under all variations or distributions of load or stress to which subjected.

y of a Fixed Body—Is power of remaining *in equilibrio* without eviation of position, notwithstanding load or stress to which it bmitted may have certain directions.

y of a Floating Body.—A body in a fluid floats, or is balanced, isplaces a volume of the fluid, weight of which is equal to weight nd when centre of gravity of body and that of volume of fluid dis- in same vertical plane.

. body *in equilibrio* is free to move, and is caused to deviate in a ree from its position of equilibrium, if it tends to return to its osition, its equilibrium is termed *Stable*; if it does not tend to de- her, or to recover its original position, its equilibrium is termed *;* and when it tends to deviate further from its original position, rium is *Unstable.*

in equilibrio may be stable for one direction of stress, and unstable r.

of Stability of a body or structure resting upon a plane is mo- *uple* of forces, which must be applied in a plane vertically inclined y in addition to its weight, in order to remove centre of resistance pon plane, or of the joint, to its extreme position consistent with The couple generally consists of the thrust of an adjoining struct- arch and pressure of water, or of a mass of earth against the together with the equal and parallel, but not directly opposed, re- plane of foundation or joint of structure to that lateral thrust. fer according to position of axis of applied couple.

–Two forces of equal magnitude applied to same body or struct- illel and opposite directions, but not in same line of action, consti- ple.

For Statical and Dynamical Stability, see Naval Architecture, page 649.

ertain Stability of a Body on a Horizontal Plane. —Fig. 1.

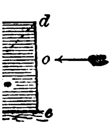


ILLUSTRATION.—Stability of a body, A, Fig. 1, when a thrust is applied as at *o*, to turn it on *a*, is ascertained by multiplying its weight by distance *a s*, from fulcrum *a* to line of centre of gravity, *c s*.

Hence, if cubical block weighed 10 tons and its base is 6 feet, its moment would be $10 \times \frac{6}{2}$ =

If upper part, *a b d c*, was remov

h but 5 tons, but its centre of gravity • would be $\frac{2}{3}$

would be $5 \times 4 = 20$ *tons*, although it is but half the

mpute Weight of a Given Body to Given Thrust.

F representing thrust in lbs., h height of centre of grav.

e of fulcrum from centre of gravity = a s.

ON.—Assume figure to be extended to a height of 20 feet of resisting the extreme pressure of wind.

Pressure estimated at 50 lbs. $F = 6 \times 20 \times 50 = 6000$ lbs. *at centre of gravity of surface of body.*

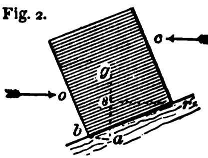
$$\text{Then } \frac{6000 \times 10}{3} = 20\,000 \textit{ lbs.}$$

NOTE 1.—This result is to be increased proportionately with the factor of [illegible] due to character of its material and structure.

2.—If form of body has a cylindrical section, as a round tower, the thrust of [illegible] would be but one half of that of a plane surface.

When the Body is Tapered, as Frustum of Pyramid or Cone.—Ascertain centres of gravity of surface for pressure or thrust, and of body for its stability, and proceed as before.

Fig. 2.



To Ascertain Stability of a Body on an Inclination.—Fig. 2.

ILLUSTRATION.—Stability of body, Fig. 2, when [illegible] is applied at *c*, is ascertained by multiplying its weight by distance *a b* from fulcrum, *b*, to line of centre of gravity, *a g*.

If thrust was applied at *o*, stability would be [illegible]tained by distance *s r* from fulcrum *r*.

Angles of Equilibrium at which various Substances will Repose, as determined by a Clinometer.

Angle measured from a Horizontal Plane, and falling from a spout.

	Degrees.		Degrees.		D[illegible]
Lime-dust	45	Sand, less dry	39.6	Common mold	3[illegible]
Dry sand	40	Wheat	37	Common gravel	3[illegible]
Moist sand	41	Corn	37	Stones or Coal	4[illegible]

Weight of a Cube Foot of Materials of Embankments, Walls, and Dams.

Concrete in cement	137	Gravel	125	Clay	[illegible]
Stone masonry	130	Loam	126	Marl	[illegible]
Brick "	112	Sand	120		

Revetment Walls.

When a wall sustains a pressure of earth, sand, or any loose material, it is termed a Revetment wall, and when erected to arrest the fall or subsidence of a natural bank of earth, it is termed a Face wall.

When earth or banking is level with top of wall, it is termed a Scarp revetment, and when it is above it, or *surcharged*, a Counterscarp revetment.

When face of wall is battered, it is termed Sloping, and when back is battered, Countersloping.

Thrust of earth, etc., upon a wall is caused by a certain portion, in shape of a wedge, tending to break away from the general mass. The pressure thus caused is similar to that of water, but weight of the material must be reduced by a particular ratio dependent upon angle of natural slope, which varies from 45° to 60° (measured from vertical) in earth of mean density.

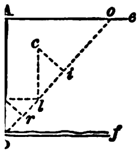
Or, natural slope of earth or like material lessens the thrust, as the [illegible] slope.

[illegible]e which line of rupture makes with vertical is .5 of angle which [illegible] [illegible]l slope, or *angle of repose*, makes with same vertical line. [illegible]

[illegible] top, its pressure may be ascertained by considering [illegible] cube foot of which is equal to weight of a cube foot [illegible] [illegible]y square of tangent of .5 angle included between [illegible]

refore squares of the tangents of .5 of 45° and .5 of 60° = .1716 and which are the multipliers to be used in ordinary cases to reduce a foot of material to a cube foot of equivalent fluid, which will have effect as earth by its pressure upon a wall.

Pressure of Earth against Revetment Walls.



Let A B C D, Fig. 3, be vertical section of a revetment wall, behind which is a bank of earth, A D f e; let D o represent *angle of repose*, *line of rupture*, or *natural slope* which earth would assume but for resistance of wall.

In sandy or loose earth angle o D A is generally 30°; in firmer earth it is 36°; and in some instances it is 45°.

If upper surface of earth and wall which supports it are both in one horizontal plane, then the resultant, $l\ n$, of pressure of the bank, behind a vertical wall, is at a distance, D n, of one third A D.

of Rupture behind a wall supporting a bank of vegetable earth is at nce A o from interior face, A D = .618 height of it.

n bank is of sand, A o = .677 h; when of earth and small gravel = ; and when of earth and large gravel = .618 h.

prism, vertical section of which is A D o, has a tendency to descend inclined plane, o D, by its gravity; but it is retained in its place by nce of wall, and by its cohesion to and friction upon face o D. Each se forces may be resolved into one which will be perpendicular to o D, to another which will be parallel to o D. The lines $c\ i$, $i\ l$ represent nents of the force of gravity, which is represented by vertical line $c\ l$, from centre of gravity, c, of prism. Lines $n\ r$, $l\ r$ represent compo of forces of cohesion and friction, which is represented by horizontal l. Force that gives the prism a tendency to descend is $i\ l$, and that d to this is $r\ l$, together with effects of cohesion and friction.

s, $i\ l = r\ l$ + cohesion + friction. Consequently, exact solution of prob f this nature must be in a great measure experimental.

as been found, however, and confirmed experimentally, that angle 1 with vertical, by prism of earth that exerts greatest horizontal stress t a wall, is *half the angle* which *angle of repose* or *natural slope* of makes with vertical.

Memoranda.

ral slope of dry sand = 39°, moist soil = 43°, very fine sand = 21°, wet clay and gravel = 35°.

etting or founding of retaining walls, if earth upon which wall is to rest is or wet, coefficient of friction between wall and earth falls to .3; hence it is ary, in order to meet this, that the wall should be set to such a depth in the hat the passive resistance of it on outer face of wall, combined with its fric i its bottom, may withstand the pressure or thrust on its inner face.

ent of a Retaining Wall is its weight multiplied by distance of its centre of to vertical plane passing through outer edge of its base.

ent of Pressure of Earth against a retaining wall is pressure multiplied by e of its centre of pressure to horizontal plane passing through base of wall.

librium of Retaining Wall is when respective moments of wall and earth are

lity of a Retaining Wall should be in excess of its equilibri er of thrust upon it, and the line of its resistance should b tance from vertical passing through centre of gravity of wa of exterior axis of wall from this line.

cient of Stability varies with character of earth, location, *ods, etc.*; hence thickness of base of wall will vary from

of retaining walls should be laid rough, in order to arrest *ing.*

When filling is composed of bowlders and gravel, the thickness of wall must be increased, and contrariwise; when of earth in layers and well rammed, it may be decreased.

Courses of dry wall should be inclined inwards, in order to arrest the flow of water of subsidence in filling from running out upon face of wall.

Less the natural slope, greater the pressure on wall.

Sea walls should have an increased proportion of breadth, as the earth backing is not only subjected to being flooded, but the walls have at times to sustain the weight of heavy merchandise.

Buttress.—An increased and projecting width of wall on its front, at intervals in its length.

Counterfort.—An increased and projecting width of wall at its back and at intervals.

Coefficient of Friction of masonry on masonry .67, of masonry on dry clay .5, and on wet clay .3.

Face of wall should not be battered to exceed 1 to 1.25 ins. in a foot of height, in consequence of the facility afforded by a greater inclination to the permeation of rain between the joints of the courses.

Footing of a wall, projecting beyond its faces, is not included in its width.

Pressure.—Limit of pressure on masonry 12 500 to 16 500 lbs. per sq. foot wall.

Thickness of Walls, in Mortar, Faces vertical. For Railways or Like Stress.

Cut stone or Ranged rubble......... .35 | Brick or Dressed rubble...........4

When laid dry, add one fourth.

Friction in vegetable earths is .5; pressure in sand .4.

When vegetable earths are well laid in courses, the thrust is reduced .5.

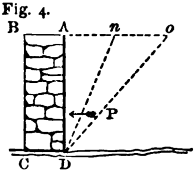
When bank is liable to be saturated with water, thickness of wall should be doubled.

Centre of Pressure of earthwork, etc., coincides with centre of pressure of wall, and hence, when surface is a rectangle, it is at .33 of height from base.

The theory of required thickness of a retaining wall, as before stated, is, that the lateral thrust of a bank of earth with a horizontal surface is that due to the prism or wedge-shaped volume, included between the vertical inner face of the wall and a line bisecting the angle between the wall and the angle of repose of the material.

To Compute Elements of Revetment Walls.—Fig. 4.

Fig. 4.



Let A D o represent angle of repose of material, against a wall, A B C D. A D n = .5 A D o. Tan. A D n = ...

$$\text{Tan. A D } n,\ h\frac{h}{2},\ \text{or } \frac{h^2}{2}\text{ tan. A D } n = \text{V};$$

$$\frac{\text{sin. D} \times \text{D A}}{\text{sin. } o} = \text{A } o; \qquad \frac{w\,h^2}{2}\text{ tan. A D } n = p;$$

$$\frac{w\,h^2}{2}\text{ tan.}^2\text{ A D } n = \text{P}; \qquad \frac{w\,h^2}{2}\text{ tan.}^2\text{ A D } n\frac{h}{3} = \text{M};$$

$$\frac{\text{W}\,h\,x^2}{2} = m; \quad \frac{w\,h^3}{6}\text{ tan.}^2\text{ A D } n = \text{E}; \quad \frac{w\,h^3}{3}\text{ tan.}^2\text{ A D } n = \text{S}; \quad h^2\frac{\text{tan.}^2\text{ A D } n}{2}w =$$

h tan. A D $n\sqrt{\dfrac{w}{3\,\text{W}}} = x$, and h tan. A D $n\sqrt{\dfrac{2\,w}{3\,\text{W}}} = x'$. *$h$ representing height of wall in feet,* V *volume of section of prism of material* A D n *one foot in length in feet,* W *and w weights of a cube foot of wall and of material,* P, p, *and* p' ... *moments of pressure of prisms of earth* A D o *and* A D n *upon wall,* M ... *of pressure and weight on and of wall,* E *and* S *equilibrium and stability in lbs., and x and x',* C D *for weights of wall for equilibrium and stability.*

...ion.—A revetment wall, Fig. 4, of 125 lbs. per cube foot and ...ins a bank of earth having a natural slope of 52° 24', and ...r cube foot; what is pressure or thrust against it, etc.?

Tan.^{2} A D $n = .242$. Then $.492 \times 40 \times \frac{40}{2} = 393.6$ *cube feet.*

$$\frac{89.25 \times 40^2}{2} \times .492 = 35\,128.8 \text{ lbs.} \qquad \frac{89.25 \times 40^2}{2} \times .492^2 = 17\,278.8 \text{ lbs.}$$

$$\frac{89.25 \times 40^2}{2} \times .492^2 \times \frac{40}{3} = 230\,384 \text{ lbs.} \qquad 125 \times 40 \times \frac{9.6^2}{2} = 230\,400 \text{ lbs.}$$

$$40 \times .492 \sqrt{\frac{89.25}{3 \times 125}} = 9.6 \text{ feet, and } 40 \times .492 \sqrt{\frac{2 \times 89.25}{3 \times 125}} = 13.58 \text{ feet.}$$

For Rubble Walls in Mortar or Dry Rubble, add respectively to base as above tained, .14 and .42 part.

NOTE 1.—When coefficient of friction is known, use it for tan.^{2} A D n.

$h \times C =$ *base of wall for stability.* (*Molesworth.*)

—When either relative weights of equal volumes of wall and bank of earth or eir specific gravities are given, S and s may be taken for W and w.

These equations involve simply the operation of a lever, the fulcrum being at e outer edge of wall C. The moment of pressure of bank is product of lateral essure and perpendicular distance from fulcrum to line of direction of pressure.

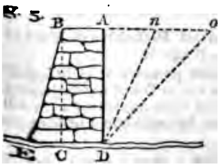
The moment of weight of wall is product of weight of wall and perpendicular stance from fulcrum to vertical line drawn through centre of gravity of wall.

When Weights of Embankment and Wall are equal per Cube Foot.

C for clay $= .336$, and for sand .267.

When Weights are as 4 *to* 5. C for clay $= .3$, and for sand .239.

When Wall has an Exterior Slope or Batter.—Fig. 5.



$$\frac{W h}{2}\left(\overline{CD + EC}^2 - \frac{EC^2}{3}\right) = M. \qquad \text{M } \textit{representing}$$

moment of weight of wall in lbs.

ILLUSTRATION.—Assume weight of wall 120 lbs. per cube foot, and C D and E C respectively 10 and 2.5 feet, and all other elements as in preceding case.

$$\text{Hence, } \frac{120 \times 40}{2} \times \left(\overline{10 + 2.5}^2 - \frac{2.5^2}{3}\right) = 370\,000 \text{ lbs.}$$

$$\frac{W h}{2}\left(\overline{x + n h}^2 - \frac{n^2 h^2}{3}\right) = \frac{w h^3}{3} \tan.^2 \text{A D } n = S.$$

r, $h\sqrt{\frac{n^2}{3} + \frac{2w}{3W}\tan.^2 \text{A D } n} - nh = x$. *$x$ representing* A B or C D. *n ratio of erence of widths of base and top to height. In absence of* tan.^{2} A D n *put* C, *co-ient of material.*

$= .0424$ for vegetable or clayey earth, mixed with large gravel; .0464 if mixed h small gravel; .1528 for sand, and .166 for semi-fluid earths.

ILLUSTRATION.—Assume elements of preceding case. $n =$ one fortieth, and tan $n = .492$.

$$40\sqrt{\frac{1}{3 \times 40^2} + \frac{2 \times 89.25}{3 \times 125} \times .492^2} - 1 = 12.6 \text{ feet.}$$

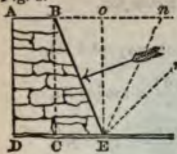
Hence, thickness of wall at base $= 12.6 + 1$ (one fortieth of he

Note.—If $n =$ one twentieth, $40\sqrt{\frac{1}{3 \times 20^2} + \frac{2 \times 89.25}{3 \times 125}} \times .$

Hence, wall at base $= 11.63 + 2$ (one twentieth of height) $=$ 1

1, 11.32 feet.

Fig. 6.



When Wall has an Interior Slope or Batter, B E, Fig. 6.

$\frac{w\,h^2}{2} \times \tan.^2 \frac{o\,E\,r}{2} = P.$ $\frac{w\,h^3}{6} \times \tan.^2 \frac{o\,E\,r}{2} =$ M *of earth for equilibrium;* $\frac{w\,h}{2}\left(D\,C \times \overline{D\,C + C\,E} - \frac{C\,E}{}\right.$ M *of wall;* and $\frac{w\,h^3}{3} \times \tan.^2 o\,E\,n =$ M *of earth for stability.*

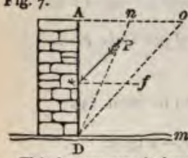
Coefficients for Batter of following Proportions.

Base = Height × Tab. number.

Batter of Wall.	Weight of Earth to Wall. As 4 to 5. Clay.	Sand.	As 1 to 1. Clay.	Sand.	Batter of Wall.	Weight of Earth to Wall. As 4 to 5. Clay.	Sand.	As 1 to 1. Clay.
1 in 4......	.083	.029	.115	.054	1 in 8......	.184	.125	.218
1 " 5......	.122	.065	.155	.092	1 " 12.....	.221	.16	.256
1 " 6......	.149	.092	.183	.118	Vertical....	.3	.239	.336

To Compute Pressure Perpendicular to Back of Wall. —Fig. 7.

Fig. 7.



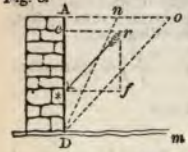
$P * = \frac{A\,D}{3}$ or $\frac{h}{3}$, and $f *$ *at right angle to back of wall, whether vertical or inclined.*

$\frac{L \times A\,n}{h}$, or $L \times \tan.\ A\,D\,n$, or $\frac{w \times h^2 \times \tan.^2 A\,D\,n}{2}$, or $\frac{w \times A\,n^2}{2} = f *$. L *representing weight of triangle of embankment, as* A D *n.*

This is pressure independent of friction between surfaces of wall and earth.

To Ascertain and Compute Amount and Effect of Friction of Wall and Earth.—Fig. 8.

Fig. 8.



Draw $f *$ by scale to computed pressure at right angle to back of wall, draw angle $f * r = m\,D\,o$ of natural slope of earth with horizon, draw $f\,r$ at right angle to $f *$, make $r\,c = f *$, then $c\,r$ will represent by scale effect of friction against back of wall.

Assume friction to act at point $*$, then $r *$ will give by scale resultant of the two forces of pressure and friction, equal to pressure in force and direction, which is against wall.

This resultant is also equal to $f * \times$ sec. $m\,D\,o$.

$\frac{L \times A\,n \times \text{sec.}\ m\,D\,o}{h} = r *$, or $\frac{w \times h^2 \times \tan.^2 m\,D\,o}{2} \times$ sec. $m\,D\,o$, or $L \times \tan.$ ... $\times$ sec. $m\,D\,o$.

To Ascertain Point of Moment of Pressure of a Wall. —Fig. 9.

Fig. 9.

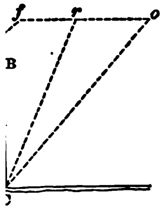
By its resisting lever l a, added to its weight.

Weight of wall as computed assumed as concentrated at its centre of gravity •.

Draw a vertical line • o through its centre of gravity, and continue line of pressure P * to l, take any distance $r\,o$ by scale representing weight of wall, and $r\,n$, by same scale, for amount of pressure or thrust against wall, complete parallelogram $r\,o\,u\,n$, then diagonal $r\,u$ will give resultant of pressure in amount and direction to overturn wall.

For stability this diagonal should fall inside of base at not less than one third of its breadth.

Surcharged Revetments.



When the earth stands above a wall, as A B e, Fig. 10, with its natural slope, A f, A B C is termed a *Surcharged Revetment.*

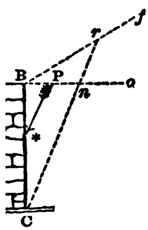
If C r is line of rupture, A f r C is the part of earth that presses upon wall, which part must be taken into the computation, with exception of portion A B e, which rests upon wall; that is, the computation must be for part C e f r, which must be reduced by multiplying weight of a cube foot of it by square of tangent of angle e C r = angle of line of rupture, or half angle e C o, which natural slope makes with vertical, and then proceed as in previous cases for revetments.

$\frac{h' w \tan.^2 e C r}{3 h W}$ = *breadth* or C D. W *and w representing weights of wall and* *ment in lbs. per cube foot, and h' height of embankment, as* C e.

TRATION.—Height of a surcharged revetment, B C, Fig. 10, is 12 feet, weight per cube foot; what is its width or base to resist pressure of earth of a weight bs. per cube foot, and a height, C e, of 15 feet, angle of repose 45°?

$^2(45° \div 2) = .1716$. Then $15\sqrt{\frac{15 \times 100 \times .1716}{3 \times 12 \times 130}} = 15\sqrt{.055} = 3.52$ *feet.*

...scertain Point of Moment of Pressure of a Surcharged Wall.—Fig. 11.



Draw a line, P $*$, parallel to slope, C r, through centre of gravity of sustained backing, B C r.

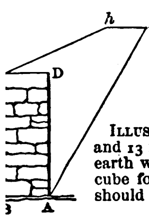
When, as in this case, this section is that of a triangle, point $*$ will be at .33 height of wall.

When natural slope is 1.5 in length to 1 in height, as with gravel or sand, $w \times .64$ = pressure P $*$.

In a surcharged revetment, as f B o, at its natural slope, the maximum pressure is attained when the backing reaches to r. When slope of maximum pressure, C n r, intersects face of natural slope, B f, so that if backing is raised to f, or above it, there is theoretically no additional stress exerted at back of or against wall, but practically there is, from effect of impact of vibration of a train, proximity to percussive action, alike to that of a trip-hammer, etc.

...n backing rests on top of wall, as A B e, Fig. 10, small triangle of it is omitted ...putations. Direction of pressure against wall is same as when wall is not ...ged.

When Wall is set below Surface of Earth.—Fig. 12.



$$1.4\ \overline{\tan. 45° - \frac{a}{e}}\sqrt{\frac{h^2 w \left(\tan. 45° - \frac{a}{2}\right)^2 \backsim 2 f V}{W}} = d.$$

a representing angle of repose of earth, w and W *weights of earth and wall per cube foot, f friction of wall on base* A B, *and* V *weight of wall.*

ILLUSTRATION.—If a wall of masonry, Fig. 12, 8 feet in thickness and 13 in height, is to sustain earth level with its upper surface, earth weighing 100 lbs. per cube foot, weight of wall 150 lbs. per cube foot = 15600 lbs., and angle of repose of earth 30°; what should be the depth of wall below surface of earth?

$$\text{Tan. } \overline{45 - 30 \div 2} = .5774, \text{ and } f = .3.$$

$$1.4 \times .5774\sqrt{\frac{13^2 \times 100 \times .5774^2 \backsim 2 \times .3 \times 15600}{150}} = .8084 \times \sqrt{\frac{9360 \backsim 5634.3}{150}}$$

...7 *feet.*

...—*Coefficient of stability is assumed by French engineers for walls of for* ...*1.4 h, and if ground is clayey or wet f* = .3.

Fig. 13.

In Computing Stability of a Surcharged Wall, Fig. 13, *substitute d for h, as in following illustration.* (*Molesworth.*)

d, representing depth at distance l, $= h$.

In slopes of 1 to 1, $d = 1.71\,h$; of 1.5 to 1, $= 1.55$; of 2 to 1, $=$ 1.45; of 3 to 1, $= 1.31$, and 4 to 1, $= 1.24$.

To Determine Form of a Pier to Sustain equal Pressure per Unit of Surface at all its Horizontal Sections, or any Height.

$A\,n^d = a$, or $A\,N = a$. *A and a representing areas of sections at summit of pier and at any depth, d, measured from summit, n a number the hyp. log. of which* $= 1 \div$ *height,* H, *of a column of the material of which pier is constructed, due to required pressure, and* N *the number, com. log. of which* $= \dfrac{.4343\,d}{H}$.

Illustration.—Height of a pier is 20 feet, and area of section of its summit = 1 foot; what should be its areas at 10 feet and base?

$1 \div 20 = .05$, and number $= 1.0513$; $1 \times 1.0513^{10} = 1.649$ *feet;* and $1 \times 1.0513^{20} =$ 2.719 *feet.*

Counterforts are increased thicknesses of a wall at *its back*, at intervals of its length.

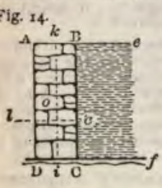
Embankment Walls and Dams.

Thrust of water upon inner face of an Embankment wall or Dam is horizontal.

When Both Faces are Vertical, Fig. 14.

Assume perpendicular embankment or wall, A B C D, Fig. 14, to sustain pressure of water, B C *e f*.

Fig. 14.



Let $k\,i$ be a vertical line passing through o, centre of gravity of wall, c centre of pressure of water, distance C c being $= .33$ B C. Draw $c\,l$ perpendicular to B C; then, since section A C of wall is rectangular, centre of gravity, o, is in its geometrical centre, and therefore $D\,i = .5$ D C. Now $l\,D\,i$ is to be considered as a bent lever, fulcrum of which is D, weight of wall acting in direction of centre of gravity, o, on arm D i, and pressure of water on arm D l, or a force equal to that pressure thrusting in direction $c\,l$.

Then $P \times D\,l = P \times \dfrac{B\,C}{3} = W \times \dfrac{D\,C}{2}$, or $P = \dfrac{3\,D\,C \cdot W}{2\,B\,C}$. P *representing pressure of water.*

Note.—When this equation holds, a wall or embankment will just be at the point of overturning; but in order that they may have complete stability, the equation should give a much larger value to P than its actual amount.

The following formulas are for walls or embankments one foot in length, for if they have stability for that length they will be stable for any other length.

$P = \dfrac{h^2}{2} w$, also $W = h\,b\,W$, each value being for 1 foot in length, which, being substituted in the equations, there will result

$\dfrac{h^2}{2} w = \dfrac{3\,b \times h\,b\,W'}{2\,h}$, or $h^2 w = 3\,b^2\,W$; $b\sqrt{\dfrac{3\,W}{w}} = h$, and $h\sqrt{\dfrac{w}{3\,W}} = b$. *h representing depth of water and wall or embankment, which are here assumed to be equal, b breadth of wall or embankment, and* W *and w weights of wall and water per cube foot in lbs.*

Which gives breadth of a wall or embankment that will just sustain pressure of the water.

To Compute Equilibrium. $h\sqrt{\frac{w}{3\,W}} = b.$

ILLUSTRATION 1.—Height of a wall, B C, equal to depth of water, is 12 feet, and re-[spec]tive weights of water and wall are 62.5 lbs. and 120 lbs. per cube foot; required [w]idth of wall, so that it may have complete stability to sustain the pressure of [wat]er.

$[12]\sqrt{\frac{62.5}{3 \times 120}} = 12 \times .4166 = 5$ *feet, breadth that will just sustain pressure of the [wat]er.*

[T]herefore an addition should be made to this to give the wall complete stability, [say] 2 feet; hence $5 + 2 = 7$, *required width of wall.*

[2.]—Width of a wall is 3 feet, and weight of a cube foot of it is 150 lbs.; required [hei]ght of wall to resist pressure of fresh water to the top.

$$3\sqrt{\frac{3 \times 150}{62.5}} = 8.049 \textit{ feet.}$$

To Compute Stability. $h\sqrt{\frac{2\,w}{3\,W}} = b.$

ILLUSTRATION.—Take elements of preceding case.

$$12\sqrt{\frac{2 \times 62.5}{3 \times 120}} = 12 \times .589 = 7.07 \textit{ feet.}$$

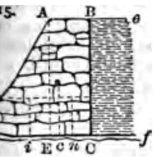
[O]r, Divide 1, 2, or 3, etc., according as the nature of the ground, the mate-[rial], and the character of the thrust of the water requires, by .05 weight of [ma]terial of wall, per cube foot, extract the square root of quotient, and mul-[tipl]y result by extreme height of water.

[EX]AMPLE.—What should be the thickness of a vertical faced wall of masonry, [hav]ing a weight of 125 lbs. per cube foot, to sustain a head of water of 40 feet, and [h]ave stability?

$$\sqrt{(2 \div \overline{.05 \times 125})}\ 40 = \sqrt{.32} \times 40 = 22.63 \textit{ feet.}$$

$$\text{Or, } h\sqrt{\frac{2\,w}{3\,W}} = 40\sqrt{.3472} = 23.56 \textit{ feet.}$$

When Dam has an Exterior Slope or Batter, as A D.—Fig. 15.

15.


Assume prismoidal wall, A B C D, to sustain pressure of water, B C $e\,f$.

Draw A E perpendicular to D C; $h = $ B C, the top breadth A B = E C = b, and bottom breadth, D E, of sloping part, A E D = S.

Then weights of portions A C and A E D respectively for one foot in length are $h\,b$ W and .5 W S h, these weights acting at points n and i respectively.

To Compute Moment.

$h\,b\,W \times \left(S + \frac{b}{2}\right) =$ *moment for* A C, and $\frac{h\,S\,W}{2} \times \frac{2\,S}{3} =$ *moment for* A E D.

[He]nce, $\frac{W\,h}{2}\left(\overline{S+b}^2 - \frac{S^2}{3}\right) =$ *moment of dam.* S *representing batter or base* E D.

[ILL]USTRATION.—Height of a dam, B C, Fig. 15, is 9 feet, base C E 3, and E D 4 feet; [what] is its moment?

$$A\,C = 9 \times 3 \times 120 \times \left(4 + \frac{3}{2}\right) = 3240 \times 5.5 = 17\,820 \textit{ lbs.}$$

$$A\,D\,E = \frac{9 \times 4 \times 120}{2} \times \frac{2 \times 4}{3} = 2160 \times 2\tfrac{2}{3} = 5760 \textit{ lbs.}$$

[He]nce, $17\,820 + 5760 = 23\,580$ lbs. moment. Or, $\frac{120 \times 9}{2}\left(\overline{4+3}^2 - \frac{4^2}{3}\right) = 540 \times 43\frac{2}{3}$ [= 23] *580 lbs. moment.*

To Compute Elements of Walls or Dams with an Exterior Batter.—Fig. 15.

To Compute Width of Top.

When Width of Batter is Given. $\sqrt{\frac{2\,h^2\,w}{3\,W}+\frac{S^2}{3}}-S=b.$

ILLUSTRATION.—Assume height of wall 9 and batter 3 feet, and W and w = 120 and 62.5 lbs. per cube foot.

$$\sqrt{\frac{2\times 9^2\times 62.5}{3\times 120}+\frac{3^2}{3}}-3=\sqrt{28.125+3}-3=2.58\textit{ feet.}$$

To Compute Width of Base.

When Width of Batter is Given. $\sqrt{\frac{2\,h^2\,w}{3\,W}+\frac{S^2}{3}}=B.$

$$\sqrt{\frac{2\times 9^2\times 62.5}{3\times 120}+\frac{3^2}{3}}=5.58\textit{ feet}=S+b.$$

To Compute Width of Batter.

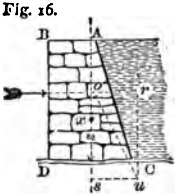
When Width of Top is Given. $\sqrt{\frac{h^2\,w}{W}+\frac{3\,b^2}{4}}-\frac{3\,b}{2}=S.$

$$\sqrt{\frac{9^2\times 62.5}{120}+\frac{3\times 2.58^2}{4}}-\frac{3\times 2.58}{2}=\sqrt{42.18+4.99}-3.87=3\textit{ feet.}$$

When Width of Bottom is Given. $\sqrt{3\,B^2-\frac{2\,h^2\,w}{W}}=S.$

To Determine Stability of a Retaining Wall or Dam by Protraction.—Fig. 16.

Fig. 16.



Assume A B C D, section of a wall. On horizontal line of centre of thrust or pressure, with a suitable scale, lay off, from vertical line of centre of gravity of wall, line $o\,r$ = thrust against wall, and on vertical line at centre of gravity of wall, at its intersection with centre of thrust, let fall $o\,s$ = weight of wall.

Complete parallelogram, and if diagonal $o\,u$ or its prolongation falls within C, the wall is stable, and W′ × distance from line $o\,s$ = moment of wall.

W *representing whole weight of wall in lbs.*

To Determine Centre of Gravity of a Wall or Dam. Fig. 16.

By Ordinates. $\frac{1}{3}\left(A\,B+C\,D-\frac{A\,B\times C\,D}{A\,B+C\,D}\right)=x$, and $\frac{B\,D}{3}\left(\frac{2\,A\,B+C\,D}{A\,B+C\,D}\right)=$

To Compute Base of Dam.

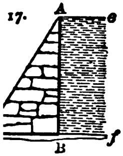
When Height, Rate of Batter, and Weight of Materials are given. RULE.—Multiply square of width of batter by .0166 weight of material per cube foot, add 1, 2, or 3 times square of depth of water, according as resistance due to equilibrium is required, divide result by .05 weight of material per cube foot, and extract square root of quotient.

Or, $\sqrt{\frac{x\,h^2+b^2\times .0166\,W}{.05\,W}}=b.$ *x = number of times of resistance required.*

Assume a dam 40 feet in height, constructed of masonry weighing ... foot, to batter 3 ins. per foot, and to have twice the resistance ... n; what should be its breadth at its base, D C?

...tter, and $\sqrt{\frac{40^2\times 2+10^2\times .0166\times 120}{.05\times 120}}=\sqrt{\frac{3399}{6}}=$

17.



When Section of Dam is a Triangle, Fig. 17. — Assume dam, A B C, to sustain a head of water, *e f*.

RULE.—Proceed as by Rule for Fig. 14; multiply by .033 instead of .05.

EXAMPLE.—As before.

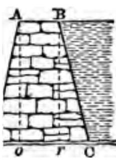
$$\sqrt{(2 \div .033 \times 125)}\ 40 = \sqrt{.485} \times 40 = 27.84 \textit{ feet.}$$

Or, Formula for S (C B), Fig. 15. $\sqrt{\frac{h^2 \times w}{W}} = 28.28$ *feet.*

'o Determine Section of a Vertical Wall which shall have Equal Resist-e of one having Section of a Triangle. (*See J. C. Trautwine, Phila.*, 1872.)

Compute Thickness of Base of a Wall or Dam.—Fig. 18.

18.



RULE.—Divide 1, 2, or 3 times square of depth of water by .05 weight of material, add quotient to .5 batter on one face, and square root of this sum, added to half batter on other side, will give thickness.

Or, $\sqrt{\frac{h^2 x}{.05\ W} + \left(\frac{b}{2}\right)^2} + \frac{b'}{2} = $ *Base.* *b and b′ representing exterior and interior batters, and x, as before, number of times of resistance or square of depth.*

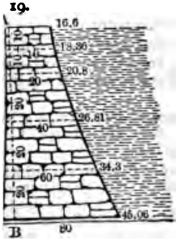
EXAMPLE.—Assume a dam 40 feet in height, to batter 5 feet on each side, constructed of masonry weighing 120 lbs. per cube , and to have twice the resistance due to its equilibrium; what should be idth of base, D C?

$$\sqrt{\frac{40^2 \times 2}{.05 \times 120} + \left(\frac{5}{2}\right)^2} + \frac{5}{2} = \sqrt{539.58} + 2.5 = 25.73 \textit{ feet.}$$

High Masonry Dams.

Rubble Masonry, well laid in strong cement, will bear with safety a load ivalent to weight of a column of it 160 feet in height. Assuming such masonry as twice weight of water, it is equivalent to a pressure of 20 000 lbs. per sq. foot.

19.



Log. B + .434 294 $\times \frac{d}{80} = b$. B *representing width of wall at top, and d depth at any desired point below top, both in feet.*

Ordinarily, B may be taken at 18 feet, and in cases of extreme and exposed heights of dam at 20 and more, and when b is determined, .9 of it is to be on outer face of wall, as A B, and .1 on inner face.

ILLUSTRATION.—Determine section of a dam, Fig. 19, 80 feet in height, at depths of 10, 20, 40, 60, and 80 feet.

Log. B = 1.2553.

og. $1.2553 + .4343 \times \frac{10}{80} = \log. 1.2553 + .0543 = 20.4$, which $\times .9 = 18.36$.

" $1.2553 + .4343 \times \frac{20}{80} = \log. 1.2553 + .1086 = 23.11$, which $\times .9 = 20.8$.

" $1.2553 + .4343 \times \frac{40}{80} = \log. 1.2553 + .2172 = 29.68$, which)

" $1.2553 + .4343 \times \frac{60}{80} = \log. 1.2553 + .3257 = 38.11$, which

$1.2553 + .4343 \times \frac{80}{80} = \log. 1.2553 + .4343 = 50.07$, whic

STEAM.

Steam is generated by heating of water until it attains tem of ebullition or vaporization, and elevation of its temperature is to indications of a thermometer up to point of ebullition; it converted into steam by additional temperature, which cannc dicated by a thermometer, and is termed latent. (See Heat, pa

Pressure and density of steam, which is generated in free contact w rises with the temperature, and reciprocally its temperature rises with ure and density, and higher the temperature more rapid the pressure. but one and a corresponding pressure and density for each temperature, generated in free contact with water is both at its maximum density and for its temperature, and in this condition it is termed *saturated*, from its capable of vaporizing more water unless its temperature is raised.

Saturated Steam is the normal condition of steam generated in free co water, and same density and same pressure always exist in conjunction temperature. It therefore is both at its condensing and generating po is, it is condensed if its temperature is reduced, and more water is eva its temperature is raised.

If, however, the whole of the water is evaporated, or a volume of satura is isolated from water, in a confined space, and an additional quantity supplied to the steam, its condition of saturation is changed, the stean *superheated*, and both temperature and pressure are increased, while its not increased. Steam, when thus surcharged, approaches to condition of

With saturated steam, pressure does not rise directly with the tempera

Steam, at its boiling-point, is equal to pressure of atmosphere, which is lbs. (page 427), at 60° upon a sq. inch.

In all computations concerning steam, it is necessary to have some or lowing elements, viz.:

Its *Pressure*, which is termed its tension or elastic force, and is expres per sq. inch. Its *Temperature*, which is number of its degrees of heat in a thermometer. Its *Density*, which is weight of a unit of its volume with that of water. Its *Relative volume*, which is space occupied by a giv or volume of it, compared with weight or volume of water that produced

Under pressure of the atmosphere alone, temperature of water cannot above its boiling-point.

Expansive force of steam of all fluids is same at their boiling-point.

A cube inch of water, evaporated under ordinary atmospheric pressure, ed into 1642* cube ins. of steam, or, in a unit of measure, very nearly 1 and it exerts a mechanical force equal to raising of $14.723\,307 \times 144 = 2$ lbs. 1 foot high.

A pressure of 1 lb. upon a sq. inch will support a column of mercury perature of 60°, $1 \div .4907769$ (page 427) $= 2.037\,586$ ins. in height; her raise a mercurial siphon gauge one half of this, or 1.018 793 ins.

Velocity of steam, when flowing into a vacuum, is about 1550 feet per se at a pressure equal to the atmosphere; when at 10 atmospheres velocity is to but 1780 feet; and when flowing into the air under a similar pressure 650 feet per second, increasing to 1600 feet for a pressure of 20 atmosphe

Boiling-points of Water, corresponding to different heights of baro Heat, page 517.

Volume of a cube foot of water evaporated into steam at 212° is 1642 hence $1 \div 1642 = .000\,609\,013$, which represents density or specific gravit t pressure of atmosphere.

Elasticity of vapor of alcohol, at all temperatures, is about 2.125 times tha

Specific Gravity, compared with air, is as weight of a cube foot of it ...al volume of air. Thus, weight of a cube foot of steam at ...mosphere is 266.124 grains; weight of a like volume of ...nd at 62° 532.679 grains. Hence $266.124 \div 532.679 =$ compared with air at 32°, and with water it is .000

* Pole's Formula makes it 1712.

Total Heat of Saturated Steam. (*Regnault.*)

From Water at 32°.

$1081.4 + .305\ T =$ *total heat.* T *representing initial temperature of water.*

ILLUSTRATION.—What is total heat of steam at 212°?

$$1081.4 + .305 \times 212 = 1146.06.$$

As Specific heat of water is .9 greater at 212° than at 32°, hence the 212° would be 212.9, and 1146.33 *the result.*

Total Heat of Gaseous Steam from Water at $32° = 1074.6 + .475\ T$.

Absorption of Heat.

In Generation of 1 Lb. of Steam at 212° from Water at 32°.

		Thermal Units.	Foot-lbs.
Sensible heat, or heat to raise temperature of water from 32° to 212°		181.8 × 772 =	139 655
Latent heat to produce steam	892.9		
" " to resist atmospheric pressure 14.7 lbs. per sq. inch	71.4	964.3 × 772 =	745 134
Total or constituent heat		1146.1	884 789

In Generation of 1 Lb. of Steam at 175 lbs. from Water at 32°.

	Thermal Units.	Foot-lbs.
Sensible heat as in preceding case from 32° to 370.8°	342.4	275 333
Latent heat to produce steam	768.2	593 050
" " to resist external pressure = 175 lbs.	83.8	64 694
Total heat from 32°	1194.4	933 077

Mechanical Equivalent of Heat Contained in Steam.

1 lb. water heated from 32° to 212° requires as much heat as would raise 180 lbs. 1°. Hence .... 181.8°

1 lb. water at 212°, converted into steam at 212° (= 14.7 lbs. pressure), absorbs as much heat as would raise 966.6 lbs. water 1°. Hence ...... 964.3°

1146.1°

Mechanical Equivalent, or maximum theoretical duty of quantity of heat in one thermal unit or one degree in 1 lb. of water, is 772 foot-lbs., which × 1146.1 *units of heat* = 884 789.2 lbs. *raised 1 foot high.*

To Compute Pressure of Steam

Above Perfect Vacuum.

When Height of Column of Mercury it will Support is given. RULE.—Divide height of column of mercury in ins. by 2.037 586, and quotient will give pressure per sq. inch in lbs.

EXAMPLE.—Height of a column of mercury is 203.7586 ins.; what pressure per sq. inch will it contain?

$$203.7586 \div 2.037\,586 = 100 \textit{ lbs.}$$

To Compute Weight of a Cube Foot of Steam.

RULE.—Multiply its density by 62.425.

EXAMPLE.—Density of a volume of steam is .000 609 013; what is its weight?

$$.000\,609\,013 \times 62.425 = .038\,016\,825 \textit{ lbs.}$$

NOTE.—See table, page 708.

1 atmosphere or 14.723 307 lbs. per sq. inch = 30 ins. of mercury.

To Compute Temperature of Steam.

RULE.—Multiply 6th root of its force in ins. of mercury by 177.2, subtract 100 from product, and remainder will give temperature in degrees.

EXAMPLE.—When elastic force of steam is equal to a pressure of 64 ins. of mercury, what is its temperature?

NOTE.—To extract *6th root* of a number, ascertain cube root of its square root.

$\sqrt{64} = 8$, and $\sqrt[3]{8} = 2$. Hence, $2 \times 177.2 - 100 = 254.4°\ t.$

Or, $\dfrac{2938.16}{6.199\,3544 - \log. p} - 371.85 = t.$ *p representing pressure in lbs.*

Saturated Steam.

Pressure, Temperature, Volume, and Density.

Pressure per Sq. Inch.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Lb.	Density, or Weight of one Cube Foot.	Pressure per Sq. Inch.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.
Lbs.	Ins.	°	°	Cub. ft.	Lb.	Lbs.	Ins.	°	°
1	2.04	102.1	1112.5	330.36	.003	58	118.08	290.4	1170
2	4.07	126.3	1119.7	172.08	.0058	59	120.12	291.6	1170.4
3	6.11	141.6	1124.6	117.52	.0085	60	122.16	292.7	1170.7
4	8.14	153.1	1128.1	89.62	.0112	61	124.19	293.8	1171.1
5	10.18	162.3	1130.9	72.66	.0138	62	126.23	294.8	1171.4
6	12.22	170.2	1133.3	61.21	.0163	63	128.26	295.9	1171.7
7	14.25	176.9	1135.3	52.94	.0189	64	130.3	296.9	1172
8	16.29	182.9	1137.2	46.69	.0214	65	132.34	298	1172.3
9	18.32	188.3	1138.8	41.79	.0239	66	134.37	299	1172.6
10	20.36	193.3	1140.3	37.84	.0264	67	136.4	300	1172.9
11	22.39	197.8	1141.7	34.63	.0289	68	138.44	300.9	1173.2
12	24.43	202	1143	31.88	.0314	69	140.48	301.9	1173.5
13	26.46	205.9	1144.2	29.57	.0338	70	142.52	302.9	1173.8
14	28.51	209.6	1145.3	27.61	.0362	71	144.55	303.9	1174.1
14.7	29.92	212	1146.1	26.36	.03802	72	146.59	304.8	1174.3
15	30.54	213.1	1146.4	25.85	.0387	73	148.62	305.7	1174.6
16	32.57	216.3	1147.4	24.32	.0411	74	150.66	306.6	1174.9
17	34.61	219.6	1148.3	22.96	.0435	75	152.69	307.5	1175.2
18	36.65	222.4	1149.2	21.78	.0459	76	154.73	308.4	1175.4
19	38.68	225.3	1150.1	20.7	.0483	77	156.77	309.3	1175.7
20	40.72	228	1150.9	19.72	.0507	78	158.8	310.2	1176
21	42.75	230.6	1151.7	18.84	.0531	79	160.84	311.1	1176.3
22	44.79	233.1	1152.5	18.09	.0555	80	162.87	312	1176.5
23	46.83	235.5	1153.2	17.26	.058	81	164.91	312.8	1176.8
24	48.86	237.8	1153.9	16.64	.0601	82	166.95	313.6	1177.1
25	50.9	240.1	1154.6	15.99	.0625	83	168.98	314.5	1177.4
26	52.93	242.3	1155.3	15.38	.065	84	171.02	315.3	1177.6
27	54.97	244.4	1155.8	14.86	.0673	85	173.05	316.1	1177.9
28	57.01	246.4	1156.4	14.37	.0696	86	175.09	316.9	1178.1
29	59.04	248.4	1157.1	13.9	.0719	87	177.13	317.8	1178.4
30	61.08	250.4	1157.8	13.46	.0743	88	179.16	318.6	1178.6
31	63.11	252.2	1158.4	13.05	.0766	89	181.2	319.4	1178.9
32	65.15	254.1	1158.9	12.67	.0789	90	183.23	320.2	1179.1
33	67.19	255.9	1159.5	12.31	.0812	91	185.27	321	1179.3
34	69.22	257.6	1160	11.97	.0835	92	187.31	321.7	1179.5
35	71.26	259.3	1160.5	11.65	.0858	93	189.34	322.5	1179.8
36	73.29	260.9	1161	11.34	.0881	94	191.38	323.3	1180
37	75.33	262.6	1161.5	11.04	.0905	95	193.41	324.1	1180.3
38	77.37	264.2	1162	10.76	.0929	96	195.45	324.8	1180.5
39	79.4	265.8	1162.5	10.51	.0952	97	197.49	325.6	1180.8
40	81.43	267.3	1162.9	10.27	.0974	98	199.52	326.3	1181
41	83.47	268.7	1163.4	10.03	.0996	99	201.56	327.1	1181.2
42	85.5	270.2	1163.8	9.81	.102	100	203.59	327.9	1181.4
43	87.54	271.6	1164.2	9.59	.1042	101	205.63	328.5	1181.6
44	89.58	273	1164.6	9.39	.1065	102	207.66	329.1	1181.8
45	91.61	274.4	1165.1	9.18	.1089	103	209.7	329.9	1182
46	93.65	275.8	1165.5	9	.1111	104	211.74	330.6	1182.2
47	95.69	277.1	1165.9	8.82	.1133	105	213.77	331.3	1182.4
48	97.72	278.4	1166.3	8.65	.1156	106	215.81	331.9	1182.6
49	99.76	279.7	1166.7	8.48	.1179	107	217.84	332.6	1182.8
50	101.8	281	1167.1	8.31	.1202	108	219.88	333.3	1183
51	103.83	282.3	1167.5	8.17	.1224	109	221.92	334	1183.3
52	105.87	283.5	1167.9	8.04	.1246	110	223.95	334.6	1183.5
53	107.9	284.7	1168.3	7.88	.1269	111	225.99	335.3	1183.7
54	109.94	285.9	1168.6	7.74	.1291	112	228.02	336	1183.9
55	111.98	287.1	1169	7.61	.1314	113	230.06	336.7	1184.1
56	114.01	288.2	1169.3	7.48	.1336	114	232.1	337.4	[illegible]
57	116.05	289.3	1169.7	7.36	.1364	115	234.13	338	[illegible]

AMPLE.—What volume of steam at 212° will raise 100 cube feet of water at 80° 2°?

$$\frac{\text{o} \times \overline{212-80}}{\text{2}+965.2-212} = 13.68 \textit{ cube feet water; } \text{or, } (13.68 \times 1642 - 212) = 22\,250 \textit{ of steam.}$$

Compute Volume of Water, at any Given Temperature, that must be Mixed with Steam to Raise or Reduce the Mixture to any Required Temperature.

ULE.—From required temperature subtract temperature of water; then rtain how often remainder is contained in required temperature subted from sum of sensible and latent heat of the steam, and quotient will volume required.

m of Sensible and Latent Heats for a range of temperatures will be found under ., pages 508 and 509.

AMPLE.—Temperature of condensing water of an engine is 80°, and required erature 100°; what is proportion of condensing water to that evaporated at a sure of 34 lbs. per sq. inch?

m of sensible and latent heats 1190.4°.

$100 - 80 = 20$. Then, $1190.4 - 100 \div 20 = 54.52$ to 1.

hen Temperature of Steam is given. $\frac{l + \overline{T - t}}{t - w} = V$. *l representing latent heat, d t temperatures of steam and required temperature, w temperature of condensing r, and* V *volume of condensing water in cube feet.*

LUSTRATION.—Temperature of steam in a cylinder is 257.6°, and other elements as in preceding example; required volume of injection water? Latent heat eam at 230° = 932.8°.

$$\frac{932.8 + \overline{257.6 - 100}}{100 - 80} = \frac{1090.4}{20} = 54.52 \textit{ volumes.}$$

Compute Temperature of Water in Condenser or Reservoir of a Steam-engine.

$\frac{\text{l}+T + \overline{V \times w}}{V + 1} = t$. ILLUSTRATION.—Assume elements as preceding.

$$\frac{932.8 + 257.6 + \overline{54.52 \times 80}}{54.52 + 1} = \frac{5552}{55.52} = 100°.$$

To Compute Latent Heat of Saturated Steam.

$15.2 - .708\, t = l$. ILLUSTRATION.—Assume temperature 257.6° as preceding.

$$1115.2 - .708 \times 257.6 = 932.8°.$$

To Compute Total Heat of Saturated Steam.

$5\, t + 1081.4 = H$. ILLUSTRATION.—Assume temperature as preceding.

$$.305 \times 257.6 + 1081.4 = 1160.$$

astic Force and Temperature of Vapors of Alcohol, Ether, Sulphuret of Carbon, Petroleum, and Turpentine.

Force in Ins. of Mercury.

	Ins.	°	Ins.	°	Ins.	°	Ins.	°	Ins.
ALCOHOL.		ALCOHOL.		ETHER.		SULPHURET OF CARBON.		PETROLEUM.	
	.4	140	13.9	34	6.2			316	30
	.86	160	22.6	54	15.3	53.5	7.4	345	44.1
	1.23	173	30	74	16.2	72.5	12.55	375	64
	1.76	180	34.73	94	24.7	110	30	OIL OF TURPENTINE.	
	2.45	200	53	96	30	212	126		
	3.4	212	67.5	104	30	279.5	300		
	4.5	220	78.5	120	39.47	347	606		
	8.1	240	111.24	150	67.6				
	10.6	264	166.1	212	178				

Saturated Steam.

Pressure, Temperature, Volume, and Density.

Pressure per Sq. Inch.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Lb.	Density, or Weight of one Cube Foot.	Pressure per Sq. Inch.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Lb.
Lbs.	Ins.	°	°	Cub. ft.	Lb.	Lbs.	Ins.	°	°	Cub. ft.
1	2.04	102.1	1112.5	330.36	.003	58	118.08	290.4	1170	7.24
2	4.07	126.3	1119.7	172.08	.0058	59	120.12	291.6	1170.4	7.12
3	6.11	141.6	1124.6	117.52	.0085	60	122.16	292.7	1170.7	7.01
4	8.14	153.1	1128.1	89.62	.0112	61	124.19	293.8	1171.1	6.9
5	10.18	162.3	1130.9	72.66	.0138	62	126.23	294.8	1171.4	6.81
6	12.22	170.2	1133.3	61.21	.0163	63	128.26	295.9	1171.7	6.7
7	14.25	176.9	1135.3	52.94	.0189	64	130.3	296.9	1172	6.6
8	16.29	182.9	1137.2	46.69	.0214	65	132.34	298	1172.3	6.49
9	18.32	188.3	1138.8	41.79	.0239	66	134.37	299	1172.6	6.41
10	20.36	193.3	1140.3	37.84	.0264	67	136.4	300	1172.9	6.32
11	22.39	197.8	1141.7	34.63	.0289	68	138.44	300.9	1173.2	6.23
12	24.43	202	1143	31.88	.0314	69	140.48	301.9	1173.5	6.15
13	26.46	205.9	1144.2	29.57	.0338	70	142.52	302.9	1173.8	6.07
14	28.51	209.6	1145.3	27.61	.0362	71	144.55	303.9	1174.1	5.99
14.7	29.92	212	1146.1	26.36	.03802	72	146.59	304.8	1174.3	5.91
15	30.54	213.1	1146.4	25.85	.0387	73	148.62	305.7	1174.6	5.83
16	32.57	216.3	1147.4	24.32	.0411	74	150.66	306.6	1174.9	5.76
17	34.61	219.6	1148.3	22.96	.0435	75	152.69	307.5	1175.2	5.68
18	36.65	222.4	1149.2	21.78	.0459	76	154.73	308.4	1175.4	5.61
19	38.68	225.3	1150.1	20.7	.0483	77	156.77	309.3	1175.7	5.54
20	40.72	228	1150.9	19.72	.0507	78	158.8	310.2	1176	5.48
21	42.75	230.6	1151.7	18.84	.0531	79	160.84	311.1	1176.3	5.41
22	44.79	233.1	1152.5	18.09	.0555	80	162.87	312	1176.5	5.35
23	46.83	235.5	1153.2	17.26	.058	81	164.91	312.8	1176.8	5.29
24	48.86	237.8	1153.9	16.64	.0601	82	166.95	313.6	1177.1	5.23
25	50.9	240.1	1154.6	15.99	.0625	83	168.98	314.5	1177.4	5.17
26	52.93	242.3	1155.3	15.38	.065	84	171.02	315.3	1177.6	5.11
27	54.97	244.4	1155.8	14.86	.0673	85	173.05	316.1	1177.9	5.05
28	57.01	246.4	1156.4	14.37	.0696	86	175.09	316.9	1178.1	5
29	59.04	248.	1157.1	13.9	.0719	87	177.13	317.8	1178.4	4.94
30	61.08	250.	1157.8	13.46	.0743	88	179.16	318.6	1178.6	4.89
31	63.11	25[illegible]	1158.4	13.05	.0766	89	181.2	319.4	1178.9	4.84
32	65.15	254.	1158.9	12.67	.0789	90	183.23	320.2	1179.1	4.79
33	67.19	255.9	1159.5	12.31	.0812	91	185.27	321	1179.3	4.74
34	69.22	257.6	1160	11.97	.0835	92	187.31	321.7	1179.5	4.69
35	71.26	259.3	1160.5	11.65	.0858	93	189.34	322.5	1179.8	4.64
36	73.29	260.9	1161	11.34	.0881	94	191.38	323.3	1180	4.6
37	75.33	262.6	1161.5	11.04	.0905	95	193.41	324.1	1180.3	4.55
38	77.37	264.2	1162	10.76	.0929	96	195.45	324.8	1180.5	4.51
39	79.4	265.8	1162.5	10.51	.0952	97	197.49	325.6	1180.8	4.46
40	81.43	267.3	1162.9	10.27	.0974	98	199.52	326.3	1181	4.42
41	83.47	268.7	1163.4	10.03	.0996	99	201.56	327.1	1181.2	4.37
42	85.	270.2	1163.8	9.81	.102	100	203.59	327.9	1181.4	4.33
43	87.54	271.6	1164.2	9.59	.1042	101	205.63	328.5	1181.6	4.29
44	89.58	273	1164.6	9.39	.1065	102	207.66	329.1	1181.8	4.25
45	91.61	274.4	1165.1	9.18	.1089	103	209.7	329.9	1182	4.21
[illegible]	93.65	275.8	1165.5	9	.1111	104	211.74	330.6	1182.2	4.18
[illegible]	95.69	277.1	1165.9	8.82	.1133	105	213.77	331.3	1182.4	4.14
[illegible]	[illegible]	278.4	1166.3	8.65	.1156	106	215.81	331.9	1182.6	4.11
[illegible]	[illegible]	[illegible]	1166.7	8.43	.1179	107	217.84	332.6	1182.8	4.07
[illegible]	[illegible]	[illegible]	[illegible]	8.31	.1202	108	219.88	333.3	1183	4.04
[illegible]	[illegible]	[illegible]	[illegible]	8.17	.1224	109	221.92	334	1183.3	4
[illegible]	[illegible]	[illegible]	[illegible]	8.04	.1246	110	223.95	334.6	1183.5	3.97
[illegible]	[illegible]	[illegible]	[illegible]	7.88	.1269	111	225.99	335.3	1183.7	3.93
[illegible]	[illegible]	[illegible]	[illegible]	7.74	.1291	112	228.02	336	1183.9	3.9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.1314	113	230.06	336.7	1184.1	3.86
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.1336	114	232.1	337.4	1184.3	3.83
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.1364	115	234.13	338	1184.5	[illegible]

Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Lb.	Density, or Weight of one Cube Foot.	Pressure per Sq. Inch.	Pressure in Mercury.	Temperature.	Total Heat from Water at 32°.	Volume of 1 Lb.	Density, or Weight of one Cube Foot.
Ins.	°	°	Cub. ft.	Lb.	Lbs.	Ins.	°	°	Cub. ft.	Lbs.
236.17	338.6	1184.7	3.77	.2649	149	303.35	357.8	1190.5	2.98	.3357
238.2	339.3	1184.9	3.74	.2652	150	305.39	358.3	1190.7	2.96	.3377
240.24	339.9	1185.1	3.71	.2674	155	315.57	361	1191.5	2.87	.3484
242.28	340.5	1185.3	3.68	.2696	160	325.75	363.4	1192.2	2.79	.359
244.31	341.1	1185.4	3.65	.2738	165	335.93	366	1192.9	2.71	.3695
246.35	341.8	1185.6	3.62	.2759	170	346.11	368.2	1193.7	2.63	.3798
248.38	342.4	1185.8	3.59	.278	175	356.29	370.8	1194.4	2.56	.3899
250.42	343	1186	3.56	.2801	180	366.47	372.9	1195.1	2.49	.4009
252.45	343.6	1186.2	3.54	.2822	185	376.65	375.3	1195.8	2.43	.4117
254.49	344.2	1186.4	3.51	.2845	190	386.83	377.5	1196.5	2.37	.4222
256.53	344.8	1186.6	3.49	.2867	195	397.01	379.7	1197.2	2.31	.4327
258.56	345.4	1186.8	3.46	.2889	200	407.19	381.7	1197.8	2.26	.4431
260.6	346	1186.9	3.44	.2911	210	427.54	386	1199.1	2.16	.4634
262.64	346.6	1187.1	3.41	.2933	220	447.9	389.9	1200.3	2.06	.4842
264.67	347.2	1187.3	3.38	.2955	230	468.26	393.8	1201.5	1.98	.5052
266.71	347.8	1187.5	3.35	.2977	240	488.62	397.5	1202.6	1.9	.5248
268.74	348.3	1187.6	3.33	.2999	250	508.98	401.1	1203.7	1.83	.5464
270.78	348.9	1187.8	3.31	.302	260	529.34	404.5	1204.8	1.76	.5669
272.81	349.5	1188	3.29	.304	270	549.7	407.9	1205.8	1.7	.5868
274.85	350.1	1188.2	3.27	.306	280	570.06	411.2	1206.8	1.64	.6081
276.89	350.6	1188.3	3.25	.308	290	590.42	414.4	1207.8	1.59	.6273
278.92	351.2	1188.5	3.22	.3101	300	610.78	417.5	1208.7	1.54	.6486
280.96	351.8	1188.7	3.2	.3121	350	712.57	430.1	1212.6	1.33	.7498
282.99	352.4	1188.9	3.18	.3142	400	814.37	444.9	1217.1	1.18	.8502
285.03	352.9	1189	3.16	.3162	450	916.17	456.7	1220.7	1.05	.9499
287.07	353.5	1189.2	3.14	.3184	500	1018	467.5	1224	.95	1.049
289.1	354	1189.4	3.12	.3206	550	1119.8	477.5	1227	.87	1.148
291.14	354.5	1189.6	3.1	.3228	600	1221.6	487	1229.9	.8	1.245
293.17	355	1189.7	3.08	.325	650	1323.4	495.6	1232.5	.74	1.342
295.21	355.6	1189.9	3.06	.3273	700	1425.8	504.1	1235.1	.69	1.4395
297.25	356.1	1190	3.04	.3294	800	1628.7	519.5	1239.8	.61	1.6322
299.28	356.7	1190.2	3.02	.3315	900	1832.3	533.6	1244.2	.55	1.8235
301.32	357.2	1190.3	3.	.3336	1000	2035.9	546.5	1248.1	.5	2.014

Saturated Steam from 32° to 212°. (*Claudel.*)

Pressure. Mercury.	Pressure. Per Sq. Inch.	Weight of 100 Cub. Feet.	Volume of 1 Lb.	Temperature.	Pressure. Mercury.	Pressure. Per Sq. Inch.	Weight of 100 Cub. Feet.	Volume of 1 Lb.
Ins.	Lbs.	Lb.	Cub. Feet.	°	Ins.	Lbs.	Lbs.	Cub. Feet.
.181	.089	.031	3226	125	3.933	1.932	.554	180.5
.204	.1	.034	2941	130	4.509	2.215	.63	158.7
.248	.122	.041	2439	135	5.174	2.542	.714	140.1
.299	.147	.049	2041	140	5.86	2.879	.806	124.1
.362	.178	.059	1695	145	6.662	3.273	.909	110
.426	.214	.07	1429	150	7.548	3.708	1.022	97.8
.517	.254	.082	1220	155	8.535	4.193	1.145	87.3
.619	.304	.097	1031	160	9.63	4.731	1.333	75
.733	.36	.114	877.2	165	10.843	5.327	1.432	69.8
.869	.427	.134	746.3	170	12.183	5.985	1.602	62.4
1.024	.503	.156	641	175	13.654	6.708	1.774	56.4
1.205	.592	.182	549.5	180	15.291	7.511	[illegible]	50.8
1.41	.693	.212	471.7	185	17.041	8.375		
1.647	.809	.245	408.2	190	19.001	9.335		
1.917	.942	.283	353.4	195	21.139	10.385		
2.229	1.095	.325	307.7	200	23.461	11.526		
2.579	1.267	.373	268.1	205	25.994	12.77		
2.976	1.462	.426	234.7	210	28.753	14.127		
3.43	1.685	.488	204.9	212	29.922	14.7		

Points of Expansion.

Relative points of expansion, including clearance 5 per cent., assuming stroke of piston to be divided as follows, and initial pressure = 1.

Point.....	1	.75	.6875	.625	.5625	.5	.4375	.375	.333	.25	.2	.125	
Ratio.....	1	1.31	1.43	1.55	1.71	1.91	2.15	2.43	2.74	3.5	4.4	6.	

Hyp. Log. of above Ratios.

.0 1.27 1.36 1.44 1.54 1.65 1.77 1.9 2 2.25 2.43 2.79

Receiver of Compound Engines.

Volume—Into which the IP cylinder exhausts, should be from 1 to 1½ times the volume of it, plus that of the clearance in it, when the cranks are set at angles of 120° and 90°. When the cranks are opposite (180°) or very nearly so, the volume may be proportionately decreased.

Pressure—In a Receiver should not exceed one half that of the boiler pressure, and usually it is operated lower.

Receiver—Of a Triple compound engine need not have as great a volume, as the cranks are set at angles of 120° to each other.

If a receiver is insufficient in volume, the result is back pressure in the IP cylinder. If otherwise, it has too great a volume, the result is that of a material reduction of the pressure, when the exhaust port of the cylinder is opened, a consequent loss of external work and of efficiency.

To Compute Volume of a Receiver.

Single Compound.

Cranks at 90°. $\dfrac{A^2 \frac{\pi}{4} S\ 1.5}{1728}$ = *volume in cube feet.* A *representing area of IP cylinder, and* S *stroke of piston, both in sq. ins.*

Illustration.—Assume a compound engine having a IP cylinder of 28 ins., cranks at 90°, and stroke of piston 36 ins.; what should be volume of receiver?

$$\frac{28^2 \times \frac{3.1416}{4} \times 36 \times 1.5}{1728} = \frac{784 \times .7854 \times 54}{1728} = 19.25 \textit{ cube feet.}$$

Triple Compound.

$$\textit{Cranks at } 120^\circ \quad \frac{A^2 \frac{\pi}{3} S\ 1}{1728} = \textit{volume in cube feet.}$$

Illustration.—Assume a triple compound engine having a IP cylinder of 28 ins., cranks at 120°, and stroke of piston 36 ins.; what should be volume of receiver?

$$\frac{28^2 \times \frac{3.1416}{3} \times 36 \times 1}{1728} = \frac{784 \times 1.0472 \times 36}{1728} = 17.1 \textit{ cube feet.}$$

(The Practical Engineer.)

The practice with some is to give the receiver an equal volume with that of the cylinder from which it receives the steam.

Compute Mean Pressure of Steam upon a Piston by Hyperbolic Logarithms.

...le length of stroke of a piston, added to clearance in cylinder ...rth of stroke at which steam is cut off, added to clearance ...ient will express ratio or relative expansion of steam ...

...e number nearest to that of quotient, to the ...e gain.

...d by pressure of steam (including the ...

re) *as it enters the cylinder*, divide product by relative expansion, and tient will give mean pressure.

OTE.—Hyp. log. of any number not in table may be found by multiplying a mon log. by 2.302 585, usually by 2.3.

roceed by referring to table pp. 331-334.

XAMPLE.—Assume steam to enter a cylinder at a pressure of 50 lbs. per sq. inch, to be cut off at .25 length of stroke, stroke of piston being 10 feet; what will be n pressure?

earance assumed at 2 per cent. = .2 *feet.*

$+ .2 = 10.2$ *feet*, stroke $10 \div \overline{4 + .2} = 2.38$ *feet*. Then $10.2 \div 2.38 = 4.29$ *relative expansion.*

p. log. 4.29 (p. 332) = 1.4563, which $+ 1 = 2.4563$, and $\frac{2.4563 \times 50}{4.29} = 28.62$ *lbs.*

elative Effect of steam during expansion is obtained from preceding rule.

Mechanical Effect of steam in a cylinder is product of mean pressure in and distance through which it has passed in feet.

Effects of Expansion. (*Essentially from D. K. Clark.*)

ack Pressure is force of the uncondensed steam in a cylinder, consequent n impracticability of obtaining a perfect vacuum, and is opposed to the se of a piston. It varies from 2 to 5 lbs. per sq. inch.

must be deducted from average pressure. Thus: assume pressure 60 lbs., e of piston as in preceding case, and back pressure 2 lbs.

At termination of.....	1st,	2d,	3d,	4th,	5th,	and 6th foot of stroke.
Pressure..............	60	30	20	15	12	10 lbs. per inch.
Back pressure........	2	2	2	2	2	2 " " "
Effective pressure.....	58	28	18	13	10	8 " " "

otal work done by expansion at termination of each foot or assumed sion of stroke of piston is represented by hyp. log. of ratio of expansion, al work = 1.

hus, for a stroke of 10 feet and a pressure of 10 lbs.:

nd of	1st,	2d,	3d,	4th,	5th,	6th,	7th,	8th,	9th, and	10th *foot.*
n is expanded o vols., hyp. of which... =		.69	1.1	1.39	1.61	1.79	1.95	2.08	2.2	2.3
l duty...........	1	1	1	1	1	1	1	1	1	1
l duty	1	1.69	2.1	2.39	2.61	2.79	2.95	3.08	3.2	3.3
l duty is represented by 10..	10	16.9	21	23.9	26.1	27.9	29.5	30.8	32	33
tance for each t of stroke... =	2	4	6	8	10	12	14	16	18	20
l effective ty ...... =	8	12.9	15	15.9	16.1	15.9	15.5	14.8	14	13
by expansion	0	61.25	87.5	98.75	101.25	98.75	93.75	85	75	62.5

e same results would be produced if expansion was applied to a non-condensing engine, exhausting into the atmosphere.

ain, assume total initial pressure in a non-condensing cylinder ... sq. expanded 5 times, or down to 15 lbs., and then exhausted against ... atmosphere and friction of 15 lbs.

mination of.......	1st,	2d,	3d,	4th, and	5th
duty.............	1	1.69	2.1	2.39	2.
" performed...	75	126.75	157.5	179.25	195
back pressure....	15	30	45	60	75
effective duty....	60	96.75	112.5	119.25	120
by expansion.....	0	61.25	87.5	98.75	101.

n which it appears that the total duty performed by expanding ial volume is full 2.5 times, or as 75 to 195.75.

Relative Effect of Equal Volumes of Steam.

Relative total effect or work of steam is directly as its mean or average pressure (A), and inversely as its final pressure (B), or volume of steam condensed.

If former is divided by latter, quotient will give relative total effect or work of a given volume of steam as admitted and cut off at different points of stroke of piston, with a clearance of 3.125 per cent.

In following computations resistance of back pressure is omitted. If this pressure is uniform with all the ratios of expansion, it is a uniform pressure, to be deducted from the total mean pressure in column (A).

Cut off at	Pressure. (A) Mean.	(B) Final.	(C) Relative Effect.	Cut off at	Pressure. (A) Mean.	(B) Final.	(C) Relative Effect.
1	1	1	1	.375	.761	.394	1.93
.75	.969	.787	1.28	.33	.702	.335	2.09
.6875	.946	.697	1.35	.25	.628	.273	2.3
.625	.924	.636	1.45	.2	.559	.224	2.49
.5625	.889	.576	1.54	.125	.435	.15	2.9
.5	.857	.501	1.71	.1	.418	.13	3.21

To Compute Total Effective Work in One Stroke of Piston, or as Given by an Indicator Diagram.

$a\,P\,(l'\,\overline{1+\text{hyp. log. R}}-c)=w$, and $a\,b\,L=w'$. *w representing total work, and w' back pressure.*

NOTE.—Pressure of atmosphere is to be included in computations of expansion; it is therefore to be deducted from result obtained in non-condensing engines. In condensing engines, the deduction due to imperfect vacuum must also be made, usually 2.5 lbs. per sq. inch.

ILLUSTRATION.—Assume cylinder of a condensing engine 26.1 ins. in diameter, stroke of 2 feet, pressure of steam 95 lbs. (80.3 + 14.7) per sq. inch, cut off at .5 stroke, with an average back pressure of 2 lbs. per sq. inch, and a clearance of 5 per cent.

Area of piston, deducting half area of rod = 530 *sq. ins.* $2\times5\div100=.1$ *clearance*, and $2+.1\div1+.1=1.9$ = *ratio of expansion*, and $1+$ hyp. log. $1.9=1.642$.

Then $530\times95\times\overline{1.1\times1.642}-.1-530\times2\times2=50\,350\times1.706-2120=$ [illegible]

ILLUSTRATION.—Assume cylinder of a non-condensing engine having an area of 2000 sq. ins., a stroke of 8 feet, steam at a pressure of 50 lbs. (35.3 + 14.7), cut off at .25 of stroke, and clearance .25 foot.

Ratio of expansion 3.66, back pressure 17 lbs., and $1+$ hyp. log. $3.66=2.297$.

$2000\times50\,(2.25\times\overline{1+\text{hyp. log. }3.66}-.25)=100\,000\times\overline{2.25\times1+1.297}-$ [illegible] $=$ 460 575 *foot-lbs.*

$2000\times17\times8=272\,000$ *foot-lbs.* or *negative effect*, and $460\,575-272\,000=$ [illegible] *foot-lbs.*

Total Effect of One Lb. of Expanded Steam.

If 1 lb. of water is converted into steam of atmospheric pressure = 14.7 *lbs.* per sq. inch, or 2116.8 *lbs.* per sq. foot, it occupies a volume equal to 26.36 *cube feet*, and the effect of this volume under one atmosphere = 2116.8 *lbs.* × 26.36 *feet* = 55 799 *foot-lbs.* Equivalent quantity of heat expended is 1 unit per 772 *foot-lbs.* = 55 799 ÷ 772 = 72.3 *units.* This is effect of 1 lb. of steam of a pressure of one atmosphere on a piston without expansion.

Gross effect thus attained on a piston by 1 lb. of steam, generated at pressures varying from 15 to 100 lbs. per sq. inch, varies from 56 000 to 62 000 *foot-lbs.*, equivalent to from 72 to 80 *units of heat.*

Effect of 1 lb. of steam, without expansion, as thus exemplified, is reduced by clearance according to proportion it bears to volume of cylinder. If clearance is 5 per cent. of stroke, then 105 parts of steam are consumed in the work of a stroke, which is represented by 100 parts, and effect of a given weight of steam without expansion, admitted for full stroke, is reduced in ratio of 105 to 100. Having determined, by this ratio, effect of work by 1 lb. of steam without expansion, as reduced by clearance, effect for various ratios of expansion may be deduced from the terms of relative operation of equal weights of steam.

ıme of 1 lb. of saturated steam of 100 lbs. per sq. inch is 4.33 cube feet, and re per sq. foot is $144 \times 100 = 14\,400$ *lbs.;* then total initial work $= 14\,400 \times 4.33$ 52 *foot-lbs.* This amount is to be reduced for clearance assumed at 7 per cent.

a $62\,352 \times \overline{100 \div 107} = 58\,273$ *foot-lbs.*, which, divided by 772 (Joule's equiva- $= 75.5$ *units of heat.*

ıl or constituent heat of steam of 100 lbs. pressure per sq. inch, computed from perature of 212°, is 1001.4 units; and from 102° (temperature of condenser a pressure of 1 lb.) the constituent heat is 1111.4 units.

ivalent, then, of net simple effect 75.5 units is 7.5 per cent. of total heat from ›r 6.7 per cent. from 102°.

ən steam is cut off at

.75 .5 .33 .25 .2 .125 and .1 of stroke,

ırative effects are as

1.26 1.616 1.92 2.14 2.27 2.51 and 2.6.

ıl effects as given in table, page 718.

ct of 1 lb. of steam, without deduction for back pressure or other effects, varies ıbout 60 000 *foot-lbs.*, without expansion, to about double that, or 120 000 *foot-* 'hen expanded 3 times, cutting off at about 27 per cent. of stroke; and to 150 000 *foot-lbs.* when expanded about 6 times, and cut off at about 10 per ›f stroke.

Effect of Clearance.

arance varies with length of stroke compared with diameter of cylinder, form of valve, as poppet, slide, etc.

th a diameter of cylinder of 48 ins., and a stroke of 10 feet, and poppet s, clearance is but 3 per cent., and with a diameter of 34 ins. and a ə of 4.5 feet and slide valves, it is 7 per cent.

ɪSTRATION OF EFFECT. — Assume steam admitted to a cylinder for .25 of its ·, with a clearance of 7 per cent.

.n pressure for 1 lb. $= .637$, and loss by clearance $= 7 \div 100 = .07$, which, added 7, $= .707$, which is effect of a given volume of steam, if there was not any loss arance, or a gain of 11 per cent.

ən steam is cut off at........	1	.75	.5	.33	.25	.125 and	.1 stroke.
s at 7 per cent. clearance.. =	7	7.2	8.1	9.6	11	15.3	17 per cent.

Compute Net Volume of Cylinder for Given Weight of Steam, Ratio of Expansion and One Stroke.

LE.—Multiply volume of 1 lb. of steam, by given weight in lbs., by of expansion and by 100, and divide product by 100, added to per cent. arance.

.MPLE.—Pressure of steam 95 lbs., cut off at .5, weight .54 lbs., volume of 1 lb. 4.55, and weight $= .2198$ lbs., stroke of piston 2 feet, and clearance 7 per cent.

io of expansion $2 + .14 \div \overline{1 + .14} = 1.88$.

$$\frac{4.55 \times .54 \times 1.88 \times 100}{100 + 7} = \frac{461.92}{107} = 4.31 \textit{ cube feet.}$$

Compute Volume of Cylinder for Given Effect with Given Initial Pressure and Ratio of Expansion.

LE. — Divide given effect or work by total effect of 1 lb. of steam of ›ressure and ratio of expansion, and quotient will give weight of steam, which compute volume of cylinder by preceding rule.

ıMPLE.—Assume given work at 50 766 foot-lbs., and pressure and expansion as ding.

al work by 1 lb., 100 lbs. steam, cut off at .5, = by table 94 200 foot-lbs., and by of multipliers for *95 lbs.* $= .998$, which $\times 94\,200 = 94\,012$ foot-lbs.

$$\textit{Then } \frac{50\,766}{94\,012} = .54 \textit{ lbs. weight of steam.}$$

Consumption of Expanded Steam per IP of Effe[ctive Power per] Hour.

IP = 33 000, which × 60 = 1 980 000 *foot-lbs. per hour*, which steam, the quotient = weight of steam or water required per IP per

ILLUSTRATION.—Effect of 1 lb., 100 lbs. steam, without expansion, with 7 of clearance = 58 273 *foot-lbs.*, and $\frac{1\,980\,000}{58\,273} = 34$ *lbs. steam = weight of st[eam con]sumed for the effect per IP per hour.*

When steam is expanded, the weight of it per IP is less, as effect of 1 lb. is greater, and it may be ascertained by dividing 1 980 000 by the respecti[ve] or by dividing 34 lbs. by quotient of total mean pressure by final pressure, in table, page 718.

When steam is cut off at	1	.75	.5	.375	.33	.25	and .2
Volumes consumed per IP per hour........	= 34	26.9	21	18.5	17.6	16	14.9

Hence, assuming 10 lbs. steam are generated by combustion of 1 lb. coa[l] of total effect per hour,

The coal consumed per IP per hour........	= 3.4	2.69	2.1	1.85	1.76	1.6	1.49

SATURATED STEAM.

To Compute Energy and Efficiency of Saturated S[team].

$\frac{v}{V} = R$; $\frac{S}{s} = \frac{1}{r}$; $p - p' \times a$, or $\frac{X}{s}$ or $\frac{XD}{R} = P$; $\frac{33\,000}{P} = C$; $\frac{1}{S}$

$\frac{HD}{R} = H'$; $\frac{D}{R}$ or $\frac{1}{RS} = F$; $JD(t - t') + L = HD$; $\frac{HD}{D} = H$;

$p - p' \times a\,RS = X$; $\frac{\overline{HD}}{D} - XD = H''$; $\frac{H''}{R} = H'''$; $15.5\,I\,a\,S$

$h - X = h'$; $\frac{h}{RS} = P''$; $\frac{ap - ap'}{P''}$ or $\frac{X}{h} = E$; $\frac{1\,980\,000}{E}$ or $1\,980\,000$

$\frac{X}{2s} = e$; $nla\overline{p - p'} = x$, and $\frac{x}{33\,000} = IHP$; $R\overline{p - p'\,a} = x$; $FC\times$

$\frac{33\,000}{pa - p'a} =$ *cube feet.* $\frac{1\,980\,000}{62.5\,X} =$ *cube feet water evaporated per hour p*

V *and* v *representing volumes of mass of steam entering cylinder and termination of stroke of piston;* S *and* s *volumes of* 1 *lb. steam when admi[tted and] when at termination of expansion;* C *volume of cylinder per minute for ea[ch] R and r ratios of expansion and effective cut-off;* F *feed water per cube foo[t vol]ume of cylinder per stroke of piston, and f per* IHP *per hour, all in cube feet. [D den]sity or weight of* 1 *cube foot of steam at temperature of operation, in lbs.; p pressure; p′ mean back pressure;* I *initial pressure;* P *mean effective pres[sure] energy per cube foot of volume of cylinder;* P′ *pressure per sq. inch or that eq[uivalent] to heat expended, and* P″ *pressure equivalent to expenditure of available heat [en]ergy, all in lbs.* J *Joule's equivalent* = 772 *foot-lbs.;* L *as per following table, t′ absolute temperatures of steam at initial pressure and of feed water in d[egrees]* H D *heat expended per cube foot of steam admitted;* H′ *heat expended per cu[be foot] of volume of cylinder, or pressure equivalent to heat expended per sq. foot;* H″ *rejected per cube foot of steam admitted;* H‴ *heat rejected per cube foot of [volume] of cylinder;* A *available heat per* IHP *per hour; e energy per cube foot of vol[ume of] cylinder to point of cutting off, or of steam admitted; h and h′ heat expend[ed and] rejected, and* X *energy exerted, all per lb. of steam and in foot-lbs.* E *efficiency [en]ergy exerted per minute and per cube foot of steam admitted; a area of pi[ston in] sq. ins.; l length of stroke of piston in feet, and f feed water per* IHP *per ho[ur in] cube feet.*

ILLUSTRATIONS.—Assume volume of cylinder and clearance (5 per cent. = 1 cube foot, steam (86.3 + 14.7) 100 lbs. per sq. inch, cut off at .5, mean pres[sure by] rule (page 711) 86 lbs., and back pressure 3 lbs.

$V = 1$. $v = 2$. $S = 4.33$. $s = 8.31$. $p = 86$. $p' = 3$. $a =$
t and $t' = 327.9^\circ + 461.2^\circ$ and $100^\circ + 461.2^\circ$. $l = 2$ feet. $n = 1$.

$= 2$ *ratio.* $\quad 4.33 \div 8.31 = .521$ *effective cut-off.* $\quad 86 - 3 \times 144 = 11\,952$ *lbs.*

$\frac{000}{3 \times 144} = 2.76$ *cube feet.* $\quad \frac{1}{4.33} = .231$ *lbs.* $\quad \frac{.231}{2}$ or $\frac{1}{2 \times 4.33}$ $.1154$ *cube feet.*

$$772 \times .231\ (789.1^\circ - 561.2^\circ) + 157\,748 = 198\,389 \text{ foot-lbs.}$$

$\frac{98\,389}{2} = 99\,195$ *foot-lbs.* $\quad \frac{198\,389}{.231} = 858\,827$ *foot-lbs.* $\quad \frac{99\,195}{144} = 689$ *lbs.*

$$86 - 3 \times 144 \times 2 \times 4.33 = 103\,504 \text{ foot-lbs.}$$

$89 \div .231 - 103\,504 \times .231 = 174\,479$ *foot-lbs.* $\quad 174\,479 \div 2 = 87\,239$ *foot-lbs.*

$5 \times 100 \times 144 \times 4.33 = 966\,456$ *foot-lbs.* $\quad 966\,456 - 103\,504 = 862\,952$ *foot-lbs.*

$\frac{56}{.33} = 111\,600$ *lbs.* $\quad \frac{144 \times 86 - 144 \times 3}{111\,600} = .107$ E. $\quad \frac{1\,980\,000}{.107} = 18\,504\,673$ *foot-lbs.*

Or $1\,980\,000 \times \frac{966\,456}{103\,504} = 18\,504\,673$ *foot-lbs.* $\quad \frac{23\,904}{33\,000} = .725$ IP.

$1 \times 2 \times 144 \times \overline{86 - 3} = 23\,904$ *foot-lbs.* $\quad \frac{1\,980\,000}{62.5 \times 103\,504} = .306$ *cube feet.*

$2 \times \overline{86 - 3} \times 144 = 23\,904$ *foot-lbs.* $\quad .1154 \times 2.76 \times 60 = 19.11$ *cube feet.*

$\frac{103\,504}{2 \times 4.33} = 11\,952$ *foot-lbs.* $\quad \frac{33\,000}{86 \times 144 - 3 \times 144} = 2.761$ *cube feet.*

illustration of connection of expenditure of available heat (A) and consumption el, assume coal to have a total heat of combustion of 10 000 000* *foot-lbs.*, cor- nding to an equivalent evaporative power under 1 atmosphere at 212° of 13.4 vater and efficiency of furnace .5; then available heat of combustion of 1 lb. = 5 000 000 *foot-lbs.*

nce, consumption of coal per IP in an engine of like dimensions and opera- with that here given would be $19\,223\,000 \div 5\,000\,000 = 3.8444$ *lbs.*

roperties of Steam of Maximum Density. (*Rankine.*)

Per Cube Foot.

L	Temp.	L	Temp.	L	Temp.	L	Temp.	L	Temp.	L
	°		°		°		°		°	
248	95	1999	158	9 687	221	33 180	284	88 740	347	197 700
348	104	2571	167	11 760	230	38 700	293	100 500	356	219 000
481	113	3277	176	14 200	239	44 930	302	113 400	365	242 000
655	122	4136	185	17 010	248	51 920	311	127 500	374	266 600
881	131	5178	194	20 280	257	59 720	320	143 000	383	293 100
1171	140	6430	203	24 020	266	68 420	329	159 800	392	321 400
1538	149	7921	212	28 310	275	78 050	338	178 000	401	351 600

representing latent heat of evaporation per cube foot of vapor in foot-lbs. of en-
. To reduce this to units of heat divide by 772, or Joule's equivalent.

SUPERHEATED STEAM.

he results attained by imparting to steam a temperature moderately in ss of that due to the volume or density of saturated steam are:

An increase of elasticity without a corresponding increase of water evaporated.

Arresting or reducing passage of water, in suspension, to cylinder (foaming), as eat contained in that water is wholly lost without affording any elastic effect.

th of these results, by increasing effect of the steam, economize fuel.

perheated steam should be treated as a gas.

e product of its pressure, p in lbs. per sq. foot, and volume v of 1 lb. of it in cube in the perfectly gaseous condition, is obtained by following formula:

$40\ T \div t = p\,v = 85.44\ T$. $\quad T$ *temperature of steam* $+ 461.2^\circ$, and t $32^\circ + 461.2^\circ$.

USTRATION.—Assume temperature of steam, 327.9°, superheated to 341.1°.

$$\text{Then } 42\,140 \times \overline{461.2^\circ + 341.1^\circ} \div \overline{32 + 461.2^\circ} = 68\,549 \text{ foot-lbs.}$$

ice, as pressure of steam at $327.9^\circ = 100$ lbs. per sq. inch, and at 341.1° 120.

$$120 \div 100 = 1.2 \text{ to } 1 = \textit{a gain of one fifth.}$$

* Coal of average composition, $14\,133 \times 772 = 10\,910\,676$.

Relative Effect of Equal Volumes of Steam.

Relative total effect or work of steam is directly as its mean or average p[illegible] (A), and inversely as its final pressure (B), or volume of steam condensed.

If former is divided by latter, quotient will give relative total effect or wo[illegible] of a given volume of steam is admitted and cut off at different points of stro[illegible] piston, with a clearance of 3.125 per cent.

In following computations resistance of back pressure is omitted. If this p[illegible] ure is uniform with all the ratios of expansion, it is a uniform pressure wh[illegible] ducted from the total mean pressure in column (A).

Cut off at	Pressure. (A) Mean.	Pressure. (B) Final.	(C) Relative Effect.	Cut off at	Pressure. (A) Mean.	Pressure. (B) Final.	(C) [illegible]
1	1	1	1	.375	.761	.394	[illegible]
.75	.969	.787	1.28	.33	.702	.335	[illegible]
.6875	.945	.697	1.35	.25	.628	.273	[illegible]
.625	.924	.635	1.45	.2	.559	.224	[illegible]
.5625	.899	.576	1.54	.125	.435	.15	[illegible]
.5	.857	.501	1.71	.1	.418	.13	[illegible]

To Compute Total Effective Work in One Stroke of Piston, or as Given by an Indicator Diagram.

$a\,P\,(l'\ \overline{1 + \text{hyp. log. R}} - c) = w$, and $a\,b\,L = w'$. *w representing total work,* *w' back pressure.*

Note.—Pressure of atmosphere is to be included in computations of exp[illegible] It is therefore to be deducted from result obtained in non-condensing engines. [illegible] condensing engines, the deduction due to imperfect vacuum must also be ma[illegible] usually 2.5 lbs. per sq. inch.

Illustration.—Assume cylinder of a condensing engine 26.1 ins. in diameter, stroke of 2 feet, pressure of steam 95 lbs. (80.3 + 14.7) per sq. inch, cut off at .5 [illegible] with an average back pressure of 2 lbs. per sq. inch, and a clearance of 5 per cent.

Area of piston, deducting half area of rod = 530 *sq. ins.* $2 \times 5 \div 100 = .1$ *clearance*, and $2 + .1 \div 1 + .1 = 1.9$ = *ratio of expansion*, and $1 +$ hyp. log. $1.9 = 1.642$.

Then $530 \times 95 \times \overline{1.1 \times 1.642 - .1} - 530 \times 2 \times 2 = 50\,350 \times 1.706 - 2120 = 83\,777$ [illegible]

Illustration.—Assume cylinder of a non-condensing engine having an area of 2000 sq. ins., a stroke of 8 feet, steam at a pressure of 50 lbs. (35.3 + 14.7), cut off at .25 of stroke, and clearance .25 foot.

Ratio of expansion 3.66, back pressure 17 lbs., and $1 +$ hyp. log. $3.66 = 2.297$.

$2000 \times 50\ (2.25 \times \overline{1 + \text{hyp. log. } 3.66} - .25) = 100\,000 \times \overline{2.25 \times 1 + 1.297} - .25 =$ [illegible] $460\,575$ *foot-lbs.*

$2000 \times 17 \times 8 = 272\,000$ *foot-lbs.* or *negative effect*, and $460\,575 - 272\,000 = 188$ [illegible] *foot-lbs.*

Total Effect of One Lb. of Expanded Steam.

If 1 lb. of water is converted into steam of atmospheric pressure = 14.7 lbs. per sq. inch, or 2116.8 *lbs.* per sq. foot, it occupies a volume equal to 26.36 *cube feet*; and the effect of this volume under one atmosphere = 2116.8 *lbs.* × 26.36 *feet* = [illegible] *foot-lbs.* Equivalent quantity of heat expended is 1 unit per 772 *foot-lbs.* = [illegible] ÷ 772 = 72.3 *units.* This is effect of 1 lb. of steam of a pressure of one atmosphere on a piston without expansion.

[illegible] effect thus att[illegible] [illegible] by 1 lb. of steam, generated at pressure [illegible] varies from 56 000 to 62 000 *foot-lbs.*, equi[illegible]

[illegible]

[illegible]nsion, as thus exemplified, is reduced by [illegible] volume of cylinder. If clearance is [illegible] are consumed in the work of a stroke [illegible] of a given weight of steam without [illegible] in ratio of 105 to 100. Having the [illegible] of steam without expansion, as [illegible] expansion may be deduced from the [illegible] [illegible]nts of steam.

of 1 lb. of saturated steam of 100 lbs. per sq. inch is 4.33 cube feet, and r sq. foot is $144 \times 100 = 14\,400$ *lbs.*; then total initial work $= 14\,400 \times 4.33$ ot-lbs. This amount is to be reduced for clearance assumed at 7 per cent.

$52 \times \overline{100 \div 107} = 58\,273$ *foot-lbs.*, which, divided by 772 (Joule's equiva- 5 *units of heat.*

constituent heat of steam of 100 lbs. pressure per sq. inch, computed from ure of 212°, is 1001.4 units; and from 102° (temperature of condenser ssure of 1 lb.) the constituent heat is 1111.4 units.

nt, then, of net simple effect 75.5 units is 7.5 per cent. of total heat from per cent. from 102°.

am is cut off at

.75 .5 .33 .25 .2 .125 and .1 of stroke,
e effects are as
.26 1.616 1.92 2.14 2.27 2.51 and 2.6.

cts as given in table, page 718.

1 lb. of steam, without deduction for back pressure or other effects, varies 60 000 *foot-lbs.*, without expansion, to about double that, or 120 000 *foot-* expanded 3 times, cutting off at about 27 per cent. of stroke; and to 00 *foot-lbs.* when expanded about 6 times, and cut off at about 10 per oke.

Effect of Clearance.

e varies with length of stroke compared with diameter of cylinder, of valve, as poppet, slide, etc.

diameter of cylinder of 48 ins., and a stroke of 10 feet, and poppet arance is but 3 per cent., and with a diameter of 34 ins. and a .5 feet and slide valves, it is 7 per cent.

TION OF EFFECT. — Assume steam admitted to a cylinder for .25 of its a clearance of 7 per cent.

ssure for 1 lb. $= .637$, and loss by clearance $= 7 \div 100 = .07$, which, added 707, which is effect of a given volume of steam, if there was not any loss e, or a gain of 11 per cent.

am is cut off at........	1	.75	.5	.33	.25	.125 and	.1 stroke.
per cent. clearance.. =	7	7.2	8.1	9.6	11	15.3	17 per cent.

pute Net Volume of Cylinder for Given Weight Steam, Ratio of Expansion and One Stroke.

-Multiply volume of 1 lb. of steam, by given weight in lbs., by pansion and by 100, and divide product by 100, added to per cent. e.

.—Pressure of steam 95 lbs., cut off at .5, weight .54 lbs., volume of 1 lb. and weight $= .2198$ lbs., stroke of piston 2 feet, and clearance 7 per cent.

xpansion $2 + .14 \div \overline{1 + .14} = 1.88$.

$$\frac{4.55 \times .54 \times 1.88 \times 100}{100 + 7} = \frac{461.92}{107} = 4.31 \text{ cube feet.}$$

pute Volume of Cylinder for Given Effect with ven Initial Pressure and Ratio of Expansion.

- Divide given effect or work by total effect of 1 lb. of steam of re and ratio of expansion, and quotient will give weight of steam, h compute volume of cylinder by preceding rule.

.—Assume given work at 50 766 foot-lbs., and pressure and expansion as

k by 1 lb., 100 lbs. steam, cut off at .5, = by table 94 200 *foot-lbs.*, and by *tipliers for 95 lbs.* = .998, which $\times$ 94 200 = 94 012 *foot-lbs.*

Then $\dfrac{50\,766}{94\,012} = .54$ *lbs. weight of steam.*

Relative Effect of I

Relative total effect or work of ste
(A), and inversely as its final pressur
If former is divided by latter, quo
of a given volume of steam as admit
piston, with a clearance of 3.125 per
In following computations resista
ure is uniform with all the ratios o
ducted from the total mean pressur

Cut off at	Pressure. (A) Mean.	(B) Final.	(Rel Ei
1	1	1	1
.75	.969	.787	1
.6875	.946	.697	1
.625	.924	.636	
.5625	.889	.576	
.5	.857	.501	

To Compute Total Effe
ton, or as Given

$a\,P\,(l'\ \overline{1+\text{hyp. log. } R-c}) = w,$
w′ back pressure.

Note.—Pressure of atmospher
it is therefore to be deducted fro
condensing engines, the deducti
usually 2.5 lbs. per sq. inch.

Illustration.—Assume cylin
stroke of 2 feet, pressure of stea
with an average back pressure
Area of piston, deducting hal
ance, and $2+.1 \div 1+.1 = 1.9$

Then $530 \times 95 \times \overline{1.1 \times 1.642}$ —

Illustration.—Assume cyl
2000 sq. ins., a stroke of 8 feet
.25 of stroke, and clearance .2
Ratio of expansion 3.66, ba

$2000 \times 50\ (2.25 \times \overline{1+\text{hyp.}}$
460 575 *foot-lbs.*
$2000 \times 17 \times 8 = 272\,000$ *foo*
foot-lbs.

Total Effect o

If 1 lb. of water is conve
sq. inch, or 2116.8 lbs. per
of the effect of this vo
Equivalen
= 14.3 uni

ILLUSTRATION.—Assume areas of cylinders 1 and 3 sq. ins., length of stroke, pressure of steam 60 lbs. per sq. inch, cut off at 2 feet, clearance 7 per cent, area of intermediate space, as receiver, one third volume of 1st cylinder.

$R'' =$ ratio of expansion in 2d cylinder $\frac{4-1}{4} \times 3 \times 2.653 = 5.969$ lbs.

$\overline{2.653 \times 2.25 + 1 \times 2.42} - \overline{3 - 1 + 2.653 + 1 \times .42} \times 1 \times 60 = 1.7865 + 1 \times$

$\overline{2 \div 2.653 + 1 \times .42} \times 60 = 6.743 - .737 \times 60 = 360.36$ *foot-lbs.*

1st Cylinder.

Effect on piston 60 lbs. × 1 inch × 2 feet........................ = 120 foot-lbs.
" of clearance 60 lbs. × .42 foot............................... = 25.2
Total initial effect = 60 × 2 × .42.............................. = 145.2 foot-lbs.

Then $145.2 \times \overline{1 + \text{hyp. log. } 2.653}$ or 1.976........................ = 286.91 foot-lbs.
Less effect of clearance...................................... = 25.2
Net effect on piston above vacuum line........................ = 261.71 foot-lbs.
Less effect of back pressure $60 \div 2.653 = 22.61$, which, × 3 sq. ins. and 2 feet stroke .... } = 135.66 "
Net effect on piston.. = 126.05 foot-lbs.

2d Cylinder.

$145.2 \times \overline{1 + \text{hyp. log. } 2.25}$ or 1.81.............. = 262.81 *foot-lbs.*
Effect of clearance $22.61 \times 3 \times .42$............ = 28.49 " = 234.32 foot-lbs.
360.37 foot-lbs.

Intermediate reduction of pressure, as given at page 721, = .25 × 22.61 = 5.65 lbs. per sq. inch, which, × 3 sq. ins. and by 2 per foot of stroke, = 33.9 *foot-lbs.*

Hence 360.36 + 33.9 = 394.26 *foot-lbs.*

Or, by sum of the three results, viz.:

1st cylinder.. 126.05 foot-lbs.
Intermediate expansion.................................. 33.9 "
2d cylinder.. 234.32 "
394.27 foot-lbs.

WOOLF ENGINE. *D. K. Clark.*

Ratio of Expansion.—In 1st cylinder as per formula, page 710. *In 2d cylinder,* $r\,\frac{l}{l'} + x \div \overline{1 + x} =$ *ratio. r representing ratio of area of 1st cylinder to 2d, l and l' lengths of stroke and of stroke added to clearance, in ins. or feet, and x value of intermediate volume.*

ILLUSTRATION.—Assume $l = 6$ *feet,* $l' = 7$ *per cent.* $= .42$, $r = 3$, and $x = .333$.

$$\text{Then } \frac{3 \times \frac{6}{6.42} + 333}{1 + 333} = 2.353, \textit{ ratio of expansion in 2d cylinder.}$$

Total Actual Ratio of Expansion. $R'\left(r\,\frac{l}{l'} + x\right) =$ *ratio.*

—TION.—Assume preceding elements, $R = 2.653$.

$$\left(3 \times \frac{6}{6.42} + .333\right) = 2.653 \times 3.137 = 8.322, \textit{ total actual ratio}$$

Ratio of Expansion. $R'\left(r\,\frac{l}{l'} + x\right) \div \overline{1 + x} =$ ratio.

Assume preceding elements.

$$.333 + 1 + 333\Big) = \frac{8.322}{1.333} = 6.242, \text{ combined ratio}$$

Attain Combined Ratio of Expansion and Final Pressure in 2d Cylinder.

uming four cases as taken for Receiver Engine with a clearance of cent. The relations would be as follows:

diate spaces are	0	.333	.5	1	part of volume of 1st cylinder plus its clearance, or,
of 1st cylinder...............	0	.357	.535	1.07	
these 1.07, the volume of 1st ler plus its clearance, and....	1.07	1.427	1.605	2.14	total initial volumes for expansion in 2d cylinder or times volume of 1st cyl'r.
values of intermediate space the volume of 2d cylinder, ne sums are the final volumes pansion in 2d cylinder.......	3	3.357	3.535	4.07	times volume of 1st cylinder.
f expansion in 2d cyl'r are quo- of final by initial volumes..	2.804	2.352	2.202	1.902	ratios of expansion.
diate falls of pressure are, in of final pressure in 1st cylinder	0	.25	.333	.5	of final pressure; or, assuming initial pressure at 63 lbs., and final pressure at 23.75 lbs., they are
	0	5.94	7.92	11.87	*lbs. per sq. inch.*
tial pressures for expansion in linder are	1	.75	.66	.5	of final pressure in 1st cylinder, or
	23.75	17.81	15.83	11.87	*lbs. per sq. inch.*
final pressures in 2d cyl'r are..	8.47	7.57	7.19	6.24	*lbs. per sq. inch.*

Combined Ratios in these Four Cases.

					Combined Ratio.
1st.	1st ratio of expansion			.... 1 to 2.653	
	2d	do.	do.	.... 1 to 2.804	$= 2.653 \times 2.804 = 7.44.$
2d.	1st	do.	do.	.... 1 to 2.653	
	2d	do.	do.	.... 1 to 2.352	$= 2.653 \times 2.352 = 6.24.$
3d.	1st	do.	do.	.... 1 to 2.653	
	2d	do.	do.	.... 1 to 2.202	$= 2.653 \times 2.202 = 5.84.$
4th.	1st	do.	do.	.... 1 to 2.653	
	2d	do.	do.	.... 1 to 1.905	$= 2.653 \times 1.905 = 5.05.$

ial effect of steam at 63 lbs. pressure, admitted to 1st cylinder, for 2 feet, or one of stroke of piston, and with a clearance of 7 per cent. or .42 feet, is as follows:

on piston..... 63×2 feet $= 126$ *foot-lbs.*
in clearance.. $63 \times .42$ foot $= 26.46 = 63 \times 2.42 = 152.46$ *foot-lbs.* Total initial effect.

s sum is initial effect, on which effect by expansion is computed, while it is foot-lbs. in excess of the initial effect on the piston.

total effect, then, is computed as follows:

			Net Effect.
st case.	$152.46 \times (1 + \text{hyp. log. } 7.44)$ or $3.0069 =$	458.27	
	Less effect of clearance..............	26.46	431.81 *foot-lbs.*
l case.	$152.46 \times (1 + \text{hyp. log. } 6.24)$ or $2.831 =$	431.47	
	Less effect of clearance..............	26.46	405.01 "
l case.	$152.46 \times (1 + \text{hyp. log. } 5.84)$ or $2.7647 =$	421.35	
	Less effect of clearance..............	26.46	394.89 "
h case.	$152.46 \times (1 + \text{hyp. log. } 5.05)$ or $2.6294 =$	399.29	
	Less effect of clearance..............	26.46	372.83 "

reductions of net effect in 2d, 3d, and 4th cases are 6.2, 8.6, and 13.7 per cent. t in 1st case.

Compute Effect for One Stroke and a Given Combined Actual Ratio of Expansion.

E.—To hyp. log. of combined actual ratio of expansion (bel) add 1; multiply sum by period of admission of steam to *ded to clearance, and from* product subtract clearance.

iply area of 1st cylinder in sq. ins. by initial pressure of s *inch and by* **above remainder.** Product is net effect in *ke.*

Example.—Assume elements of 1st illustration page 723.

Hyp. log. 6.24 + 1 = 2.831, which, × 2.42 = 6.85, and 6.85 — .42 and × 60 = 385.8 *foot-lbs.*

Or, l' (1 + hyp. log. R′) — C × a P = E.

Comparative Effect of Steam in Receiver and Engines.

The effect of steam in a compound engine, without clearance and w intermediate reduction of pressure, is the same whether operated in a Woolf engine.

When, however, there is an intermediate space between the two cyli receiver, there is an intermediate reduction of the pressure of the ste quent upon the increase of its volume in the receiver; the reduction o therefore, being less rapid than with the Woolf engine, the effect is great

In illustration, the following comparative elements of the effect of bo is furnished.

Receiver. (7 per cent. clearance.) Woolf.

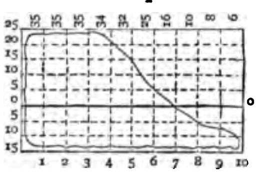
	Ratio of Expansion.	Net Effect.			Ratio of Expansion.	Net E
1st case	7.96	422.3	*foot-lbs.*	1st case	7.64	431.7
2d "	5.97	421.55	"	2d "	6.24	405.1
3d "	5.31	417.96	"	3d "	5.84	394.9
4th "	3.98	402.78	"	4th "	5.05	372.9

From which it appears, that although the effect of a receiver engine is est, its ratio of expansion is less than with the Woolf engine.

Also, that by the addition of clearance to the pistons of each engine, ratios of expansion are sensibly reduced, as compared with the ratic clearance.

INDICATOR.

To Compute Mean Pressure by an Indicat



Rule.—Divide atmosphere line, ure, into any convenient number of feet of stroke of piston, and erect p ulars at each point. Measure by parts (alike to that of diagram) t mean pressure, as defined between lines at top and bottom of diagram results, divide sum by number of p quotient will give mean pressure in sq. inch upon piston.

Example.—Pressures, as above given, are:

35 + 35 + 35 + 34 + 32 + 25 + 16 + 10 + 8 + 6 = 236, which, ÷ 10, = 2

Note.—If it were practicable to run an engine without any load, and times is, the mean pressure, as exhibited by an indicator, would be an ex ure of the friction of the engine.

Conclusions on Actual Efficiency of Steam

For development of highest efficiencies of steam, as used in an engine, protecting it from cooling and condensing in the cylinder must be employed eating of it prior to its introduction into a cylinder is probably most s that may be employed for this purpose. Application to cylinder than it is next best means; and next is the steam-jacket.

s of locomotive and portable engines, consumption of steam per ss than for that of single-cylinder condensing engines for like rat hich is due to effect of temperature of non-condensing cylinder

results that the compound engine is more effic of the two kinds of compound engines, th he Woolf.

neous coal per IHP per hour, for com Bramwell, ranged from 1.7 to 2.8 lb

Compute Volume of Water Evaporated per Lb. of Coal.

$\frac{v\,W}{d}$ = *volume of water, in lbs.* V *and* v *representing volume of steam and*
e volume of water, in cube feet, W *weight of cube foot of water, and* F *weight of*
nsumed, both in lbs., and d *density of water, in degrees of saturation.*

STRATION.—Take case at foot of page. V = 449 887 *cube feet*, v = 838 *cube*
$= 64.3$, E = 1, and F = 4061 *lbs.*

$$\frac{449\,887 \div 838 \times 64.3}{4061 \times 1} = 3.5 \textit{ lbs. per hour.}$$

in Fuel, and Initial Pressure of Steam required, when Acting Expansively, compared with Non-Expansion or Full Stroke.

of off.	Gain in Fuel.	Cutting off.	Point of Cutting off.	Gain in Fuel.	Cutting off.	Point of Cutting off.	Gain in Fuel.	Cutting off.
;.	Per Cent.	Lbs.	Stroke.	Per Cent.	Lbs.	Stroke.	Per Cent.	Lbs.
	22.4	1.03	.5	41	1.18	.25	58.2	1.67
5	32	1.09	.375	49.6	1.32	.125	67.6	2.6

STRATION.—What must be initial pressure of steam cut off at .5, to be equiv-
.o 100 lbs. per sq. inch at full stroke?

100 at full stroke = 100, and 100 × 1.18 = 118 lbs.

To Compute Gain in Fuel.

.E.—Divide relative effect of steam by number of times the steam is
ded, and divide 1 by quotient; result is the initial pressure of steam
ed to be expanded to produce a like effect to steam at full stroke.

ide this pressure by number of times the steam is expanded, and sub-
quotient from 1, remainder will give gain per cent. in fuel.

MPLE.—When steam is cut off at .5, what is gain in fuel, and what mechanical

tive effect, including clearance of 5 per cent., = 1.64; number of times of ex-
n = 2.

1.64 ÷ 2 = .82, and 1 ÷ .82 = 1.22 *initial pressure.*
1.22 ÷ 2 = .61, and 1 — .61 = .39 *per cent.*

ianical effects of steam at full and half strokes are 2 — 1.64 = .36 *difference.*

:e, 1.64 : .36 :: 50 (half volume of steam used) : 10.97 *per cent. more fuel to*
:e same effect at half stroke, compared with steam at full stroke.

' Compute Consumption of Fuel in a Furnace.

:n Dimensions of Cylinder, Pressure of Steam, Point of Cut-off, Revo-
, and Evaporation per Lb. of Fuel per Minute are given.

E.—Compute volume of cylinder to point of cutting off steam, in-
; clearance. Multiply result by number of cylinders, by twice number
kes of piston, and by 60 (minutes); divide product by density of steam
pressure in cylinder, and quotient will give number of cube feet of
:xpended in steam.

.iply number of cube feet by 64.3 for salt water (62.425 for fresh),
product by evaporation per lb. of fuel consumed, and quotient will
nsumption in lbs. per hour.

PLE.—Cylinder of a marine engine is 95 ins. in diameter by 10 feet stroke
n; pressure of steam in steam-chest is 15.3 lbs. per sq. inch, cut off at .5
number of revolutions 14.5, and evaporation estimated at 8.5 lbs. of salt
er lb. of coal; what is consumption of coal per hour, when density of water
tained at 2-32? (See Saturation, page 726.)

ie of steam at above pressure, compared with water (15.3 +
15 ins. + *2.5* per cent. for clearance ÷ 144 = 50.45 cube feet.

feet + *2.5* per cent. = 5 feet 1.5 ins., and 50.45 × 5 feet 1.5 ·
9 887 cube feet steam per hour.

Steam and Exhaust Valves.—(*Poppet*), $\frac{a\,s\,n}{24\,000}$ = *area for steam*, $\frac{a\,s\,n}{20\,000}$ *exhaust*; (*Slide*), $\frac{a\,s\,n}{30\,000}$ *for steam*, and $\frac{a\,s\,n}{22\,750}$ *for exhaust.* *a* representing

area of steam cylinder in sq. ins., s stroke of piston in ins., and n number of revolutions per minute.

Injection Pipes.—One each *Bottom* and *Side* to each condenser; each equal to supply 70 times volume of water evaporated when engine working at a maximum; and in *Marine* and *River* engines the addition of a *Bilge*, which is properly a branch of bottom pipe.

NOTE 1.—Proportions given will admit of a sufficient volume of water when engine is in operation in the Gulf Stream, where the water at times is at temperature of 84°, and volume required to give water of condensation a temperature of 70 times that of volume evaporated.

2. Velocity of flow of water through cock or valve 20 feet per second in river or shallow draught, and 30 feet in sea or deep draught service.

*Feed Pump.**—(*Single acting, Marine*), Volume, .006 to .01 steam cylinder. (*River* and *Land*), or when fresh water alone or a surface condenser is used, .004 to .007.

NON-CONDENSING.

For a Range of Pressures of from 50 to 150 lbs. (Mercurial Gauge) per Sq. Inch, Cut Off at Half Stroke.

Piston-rod.—(*Wrought Iron*), Diam., .125 to .2 steam cylinder. .8 diam.

Steam and Exhaust Valves.—Area is determined by rules given for in a condensing engine, using for divisors 30 000 and 22 750.

A decrease in volume of cylinder is not attended with a proportionate of their area, it being greater with less volume.

*Feed-pump.**—(*Single acting, Marine*), Volume, .008 to .016 steam cylinder. (*River* and *Land*), or where fresh water alone is used, .005 to .0

General Rules.

Engines.

Cylinder. Thickness.—(*Vertical*), $\frac{D\,p}{2400} = t$; (*Horizontal*), $\frac{D\,p}{2000} = t$ (*Inclined*), divide by 2000 in a ratio inversely as sine of angle of inclination.

D *representing diameter of cylinder, p extreme pressure in lbs. per sq. inch may be subjected to, and t thickness in ins.*

Shafts, Gudgeons, Journals, etc. To resist Torsion. See rules, pp. 7

Coupling Bolts. $\frac{D}{2}\sqrt{\frac{D}{n\,d'}} = d.$ *n representing number of bolts,* D d... *ft, d' distance of centre of bolts from centre of shaft, and d diameter of ins.*

...ss-head, Wrought-iron. (*Cylinder*), $\frac{a\,p\,l}{700}$ = S, and $\sqrt{\frac{S}{b}} = d$, or

...senting area of cylinder in sq ins., l length of cross-head between centres in feet, and S product of square of depth d, and breadth, b, of section

(*Air-pump*), $\frac{a\,l}{18}$ = S, and as above for *d* and *b*.

...m is cylindrical, for S put $\sqrt[3]{S \times 1.7}$.

* ...end journals same as that of piston...

...Formulas, page 73...

»e.—Its area should exceed that of steam-valve, proportionate to ıd exposure to the air.

g-rod.—Length, 2.25 times stroke of piston when it is at all to afford the space; when, however, it is imperative to reduce ion, it may be twice the stroke.

ve friction of long and short connecting-rods is, for length of stroke of r cent. additional; twice, 3 per cent.; and for thrice, 1.33.

Diam. 1 to 1.1 that of piston-rod. *Centre* of body (*Horizontal*), *Vertical*), .06 inch per foot of length of rod.

connecting-rods or links, area of necks .65 to .75 area of attached rod. econd set of rods is used, as in some air-pump connections, area of ıtio, inversely as their lengths to that of first set.

Connecting-rods, Links, etc.—(*Strap*), area at its least section attached rod; (*Gib* and *Key*), .3 diam. of neck, width, 1.25 times, times (*Draft*) of keys .6 to .8 inch per foot. Distance of *Slot* rod .5 diam. of pin.

nks, Beams, etc.). $\sqrt[3]{\frac{P\,l}{C}} \cdot 355 = d$. *P representing pressure or thrust m, l length of journal in ins., and C, for Wrought iron* = 640, *Cast*, 560. , 600, *and Cast*, 1200.

.3 to 1.5 times their diam., and pressure should not exceed 750 inch for propeller engine, and 1000 for side-wheel.

Wrought-iron).—*Hub*, compared with neck of shaft, 1.75 diam., ı. *Eye*, compared with pin, 2 diam., and 1.5 depth. *Web*, at pe- ıub, width, .7 width, and in depth .5 depth of hub; and at periph- width, .8 width, and in depth, .6 depth of eye.

ı.) Diameters of *Hub* and *Eye* respectively, twice diam. of neck d 2.25 times that of crank pin.

illets of sides of web .5 width of web at end for which fillet is designed; ack of web, .5 that at sides of their respective ends.

pen or *Trussed*.—Length from centres 1.8 to 2 stroke of piston, 5 length. If strapped, *Strap* at its least dimensions .9 area of ts depth equal to .5 its breadth. *End centre journals* each 1, and *journals* 2.5 times area of piston or driving-rod.

rtion for strap is when depth of beam is .5 length, as above; conse- n its depth is less, area of strap must be increased; and when depth of ter or less than .5 width, its area is determined by product of its $b\,d^2$, s if its depth was .5 its width.

n). *Area of Section of Centre.* $\frac{p \times \overline{l \div 2}}{500\,d} = A$. *p representing ure upon piston in lbs., d depth in ins., and l length in feet.*

centre .5 to .75 diam. of cylinder, and, when of uniform thick- ness of not less than .1 of depth.

of End Centres.—$l \div 2 - \sqrt{(l \div 2)^2 - (s \div 2)^2}$ = *vibration at each senting stroke of piston, in feet.*

Blocks (*Shaft*).—*Binder* $d\sqrt{\frac{l}{b}}\,C$ = *depth. d representing diam. two to binder, l distance between bolts, b breadth of binder, all in ins., ought iron* 1, *steel* .85, *and cast iron* .2.

own Bolts. $P \div 3\,C$ = *area at base of* thread of each bolt. C for mild *and large bolts* 6000 *and* 7000, *for wrought iron* 4500 and 6000, if b

ass). $\frac{d}{3}\sqrt{\frac{l}{b}}$ = *depth.*

Cocks.—Angles of sides of plug from 7° to 8° from plane of it.

Pumps.—Velocity of water in pump openings should not exceed 500 feet per minute.

Fly-wheels and Governors.—See Rules, pages 451 and 452.

Water-wheels.

Water-wheels (Arms).—Number from .75 to .8 diam. of wheel in feet. *(Blades) Wood.*—For a distance of from 5 to 5.5 feet between arms, thickness from .09 to .1 inch for each foot of diam. of wheel.

Area of blades, compared with area of immersed amidship section of vessel, depends upon dip of wheels, their distance apart, model and rig of vessel.

In *River service*, area of a single line of blade surface varies from .3 to that of immersed section; in *Bay* or *Sound service*, it varies from .15 to and in *Sea service*, it varies from .07 to .1.

Note.—A wrought-iron blade .625 inch thick bent at a stress withstood by oak blade 3.5 ins. thick.

Radial and Feathering.

Radial.—Loss of effect is sum of loss by oblique action of wheel blades upon the water, their slip, and thrust and drag of arms and blades as they enter and leave the water.

Loss by oblique action is computed by taking mean of square of sines of angles of blades when fully immersed in the water.

Loss by oblique action of blades of wheel of steamer *Arctic*, when her wheels were immersed 7 feet 9 ins. and 5 feet 9 ins., was 25.5 and 18.5 per cent., which was the loss of useful effect of the portion of total power developed by engine which was applied to wheels.

Feathering.—Loss of effect is confined to thrust and drag of arms and blades as they enter and leave the water.

Comparative Effects.—In two wheels of a like diameter (26 feet, and 6 feet immersion), like number and depth of blades, etc., the losses are as follows:

Radial .... 26.6 per cent. | Feathering .... 15.4 per cent.

Loss of effect by thrust and drag in a feathering wheel, having these elements and included in the above given loss, is computed at 2 per cent.

Relative loss of effect of the two wheels is, approximately, for ordinary immersions, 20 and 15 per cent. from circumference of wheel.

Centre of Pressure, $\frac{2}{3}\,\frac{d^3 - d'^3}{d^2 - d'^2} - d = c.$ *d and d' representing depths of blade below surface of water, and c centre of pressure, all in like dimensions, from edge.*

In the cases here given, centres of pressure are as follows:

Radial.................... 6.4 ins. | Feathering................ 8.5 ins.

Propellers.

Propellers (Screw).—*Pitch* should vary with area of circle described to area of midship section of vessel.

AREA, TWO-BLADED.

...r to mid-	6	5	4.5	4	3.5	3	2.5
...ter of	.8	1.02	1.11	1.2	1.27	1.31	[illegible]

..., multiply ratio of pitch to diam. as given ...am.

».—Slip of a screw propeller is directly as its pitch, and economical of a screw is inversely as its pitch; greater the pitch less the effect.

expanding pitch has less slip than a uniform pitch, and, consequently, re effective.

To Compute Thrust of a Propeller.

$\frac{217}{S} = T$. S *representing speed of vessel in knots per hour.*

SLIDE VALVES.

All Dimensions in Inches.

›ompute Lap required on Steam End, to Cut-off at any given Part of Stroke of Piston.

LE.—From length of stroke subtract length of stroke that is to be made › steam is cut off; divide remainder by stroke, and extract square f quotient.

ltiply this root by half throw of valve, from product subtract half lead, emainder will give lap required.

MPLE.—Having stroke of piston 60 ins., stroke of valve 16 ins., lap upon ex- side .5 in. = one thirty-second of valve stroke, lap upon steam side 3.25 ins., ins., steam to be cut off at five sixths stroke; what is the lap?

$- \frac{5}{6}$ of $60 = 10$. $\sqrt{\frac{10}{60}} = .408$. $.408 \times \frac{16}{2} = 3.264$, and $3.264 - \frac{2}{2} = 2.264$ *ins.*

Ascertain Lap required on Steam End, to Cut-off at various Portions of Stroke.

Valve out Lead.	Distance of piston from end of its stroke when steam is cut off, in parts of length of its stroke.									
	$\frac{1}{2}$	$\frac{5}{12}$	$\frac{1}{3}$	$\frac{7}{24}$	$\frac{1}{4}$	$\frac{5}{24}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{12}$	$\frac{1}{24}$
› parts of ke......	.354	.323	.286	.27	.25	.228	.204	.177	.144	.102

ISTRATION.—Take elements of preceding case.

ter $\frac{1}{6}$ is .204, and $.204 \times 16 = 3.264$ *ins. lap.*

›en Valve is to have Lead.—Subtract half proposed lead from lap as- ›ned by table, and remainder will give proper lap to give to valve.

hen, as last case, valve was to have 2 ins. lead, then $3.264 - 2 \div 2 = 2.264$ *ins.*

Compute at what Part of Stroke any given Lap on Steam Side will Cut off.

LE.—To lap on steam side, as determined above, add lead; divide sum ›lf length of throw of valve. From a table of natural sines (pages 390– find the arc, sine of which is equal to quotient; to this arc add 90°, from their sum subtract arc, cosine of which is equal to lap on steam divided by half throw of valve. Find cosine of remaining arc, add 1 and multiply sum by half stroke, and product will give length of that f stroke that will be made by piston before steam is cut off.

MPLE.—Take elements of preceding case.

$$\left(\sin. \frac{2.264+2}{16 \div 2} + 90^\circ - \cos. \frac{2.264}{16 \div 2}\right) + 1 \times \frac{60}{2} = \cos. (32^\circ\ 13' + 90^\circ - 73^\circ\ 34')$$

$39'$, and $\cos. 48^\circ\ 39' + 1 \times \frac{60}{2} = 1.66 \times 30 = 49.8$ *ins.*

To Ascertain Breadth of Ports.

›hrow of valve should be at least equal to lap on steam side, If this breadth does not give required area of port, throw d until required area is attained.

Portion of Stroke at which Exhausting Port is Cl[illegible] and Opened.

Lap on Exhaust Side of Valve in Parts of its Throw.	Portion of Stroke at which Steam is cut off.							Lap on Exhaust Side of Valve in Parts of its Throw.	Portion of Stroke at which Steam is cut off.						
	$\frac{1}{3}$	$\frac{7}{24}$	$\frac{1}{4}$	$\frac{5}{24}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{12}$		$\frac{1}{3}$	$\frac{7}{24}$	$\frac{1}{4}$	$\frac{5}{24}$	$\frac{1}{6}$	$\frac{1}{8}$	[illegible]
A								B							
.125	.178	.161	.143	.126	.109	.093	.074	.125	.033	.026	.019	.012	.008	[illegible]	[illegible]
.0625	.13	.118	.1	.085	.071	.058	.043	.0625	.06	.052	.04	.03	.022	[illegible]	[illegible]
.03125	.113	.101	.085	.069	.053	.043	.033	.03125	.073	.066	.051	.042	.033	[illegible]	[illegible]
0	.092	.082	.067	.055	.041	.033	.022	0	.092	.082	.067	.055	.044	[illegible]	[illegible]

Units in columns of table A express distance of piston, in parts of its stroke, [illegible] end of stroke when exhaust port in advance of it is closed; and those in col[illegible] of table B express distance of piston, in parts of its stroke, from end of its s[illegible] when exhaust port behind it is opened.

ILLUSTRATION.—A slide valve is to be cut off at one sixth from end of stroke [illegible] on exhaust side is one thirty-second of stroke of valve (16 ins.), and stroke of p[illegible] is 60 ins. At what point of stroke of piston will exhaust port in advance of i[illegible] closed and the one behind it open.

Under one sixth in table A, opposite to one thirty-second, is .053, which [illegible] length of stroke = 3.18 *ins.*; and under one sixth in table B, opposite to one thi[illegible] second, is .033, which × 60 = 1.98 *ins.*

If lap on exhaust side of this valve was increased, effect would be to cause p[illegible] advance of valve to be closed sooner and port behind it opened later. And if l[illegible] exhaust side was removed entirely, the port in advance of piston would be [illegible] and the one behind it open, at same time.

Lap on steam side should always be greater than that on exhaust side, and d[illegible] ence greater the higher the velocity of piston.

In fast-running engines, alike to locomotives, it is necessary to open exhaust [illegible] before end of stroke of piston, in order to give more time for escape of the stea[illegible]

To Compute Stroke of a Slide Valve.

RULE.—To twice lap add twice width of a steam port in ins., and s[illegible] will give stroke required.

Expansion by lap, with a slide valve operated by an eccentric alone, cann[illegible] extended beyond one third of stroke of a piston without interfering with effic[illegible] operation of valve; with a link motion, however, this distortion of the valve [illegible] somewhat compensated. When lap is increased, throw of eccentric should als[illegible] increased.

When low expansion is required, a cut-off valve should be resorted to in additi[illegible] to main valve.

To Compute Distance of a Piston from End of its Stroke, when Lead produces its Effect.

RULE.—Divide lead by width of steam port, both in ins., and term [illegible] quotient sine; multiply its corresponding versed sine by half stroke, [illegible] product will give distance of piston from end of its stroke, when steam is [illegible] mitted for return stroke and exhaustion ceases.

EXAMPLE.—Stroke of piston is 48 ins., width of port 2.5 ins., and lead .5 [illegible] what will be distance of piston from end of stroke when exhaustion commences?

$$.5 \div 2.5 = .2 = sine, \text{ ver. sin. of } .2 = .0202, \text{ and } .0202 \times \frac{48}{2} = .4848 \text{ ins.}$$

[illegible] Compute Lead, when Distance of a Piston from the End of Stroke is given.

[illegible]LE.—Divide distance in ins. by half stroke in ins., and term qu[illegible] [illegible]ultiply corresponding sine by width of steam port, and p[illegible]

[illegible] elements of preceding case.

[illegible] sin., and sine of ver. sin. .0202 = .2, and .2 × 2.5 [illegible]

ompute Distance of a Piston from End of its Stroke, when Steam is admitted for its Return Stroke.

LE.—Divide width of steam port, and also that width, less the lead, by oke of slide, and term quotients *versed sines first* and *second*. Ascer- their corresponding arcs, and multiply *versed sine* of difference between and *second* by .5 stroke, and product will give distance.

AMPLE.—Assume elements of preceding case. lap = .5 *inch*, and stroke of 6 *ins*.

$\frac{5}{-2}$ and $\frac{2.5 - .5}{6 \div 2} = .8333$, and .667 and ver. sin. $80^\circ\ 24' \sim 70^\circ\ 33' \times \frac{48}{2} = .3528$ *inch*.

o Compute Lap and Lead of Locomotive Valves.

cut off at .33, .25, and .125 of stroke of piston, lap = 289, .25, and .177 *t*, outside = .07 *t*, and inside lead = .3 *t*. *t representing stroke of valve, all in ins.*

HORSE-POWER.

orse-power is designated as *Nominal*, *Indicated*, and *Actual*.

ominal, is adopted and referred to by Manufacturers of steam-engines, rder to express capacity of an engine, elements thereof being confined imensions of steam cylinder, and a conventional pressure of steam and d of piston.

dicated, designates full capacity in the cylinder, as developed in opera- , and without any deductions for friction.

ctual, refers to its actual power as developed by its operation, involving ents of mean pressure upon piston, its velocity, and a just deduction for tion of operation of the engine.

To Compute Horse-power of an Engine.

ominal.—*Non-condensing*, $\frac{D^2 v}{1000}$, and *Condensing*, $\frac{D^2 v}{1400}$ = IP. D *repre- ng diameter of cylinder in ins., and v velocity of piston in feet per minute.*

on-condensing is based upon uniform steam-pressure of 60 lbs. per sq. (steam-gauge), cut off at .5 stroke, deducting one sixth for friction and es, with a mean velocity of piston, ranging from 250 to 450 feet per ute.

ondensing is based upon uniform steam-pressure of 30 lbs. per sq. inch am-gauge), cut off at .5 stroke, deducting one fifth for friction and es, with a mean velocity of piston of 300 feet per minute for an engine hort stroke, and of 400 feet for one of long stroke.

ctual.—*Non-condensing*. $\frac{A\,\overline{P* - (f\dagger + 14.7)}\,2\,s\,r}{33\,000}$ = IP. A *representing of cylinder in sq. ins.*, P *mean effective pressure upon cylinder piston, inclusive mosphere, f friction of engine in all its parts, added to friction of load, both in er sq. inch, s stroke of piston in feet, and r number of revolutions per minute.*

m of these resistances is from 12.5 to 20 per cent., according to pressure of , being least with highest pressure.

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h is value is best obtained by an *Indicator;* when one is not used, refer to rule able, pp. 710–12. In estimating value of P, add 14.7 lbs., for atmospheric press- o that indicated by steam gauge or safety-valve. Clearance of piston at each f cylinder is included in this estimate.

h is value may be safely estimated in engines of magnitu ... the nor ch, for friction of engine in all its parts, and friction of lo *per cent. of remaining* pressure. Sum of these resistan *es is from 10 to 20 per cent.*, according to pressure of ste *ed to deliver water of* condensation at level of discharg *For pressure representing* friction for different designs *as estimated by* English authority, see pp. 473–5 and 66.

ILLUSTRATION.—Diameter of cylinder of a non-condensing engine is 10 ins., stroke of piston 4 feet, revolutions 45 per minute, and mean pressure of steam (per gauge) 60 lbs. per sq. inch.

$A = 78.54$ *sq. ins.* $P = 60 + 14.7 = 74.7$ *lbs.* $f = 2.5 + \overline{(60 + 14.7 - 2.5)} \times .075 = 7.92$ *lbs.*

$$\text{Then } \frac{78.54 \times (60 + 14.7 - 7.92 + 14.7) \times 2 \times 4 \times 45}{33\,000} = 44.6 \text{ HP}.$$

NOTE 1.—Power of a non-condensing engine is sensibly affected by character of exhaust, as to whether it is into a heater, or through a contracted pipe, to aid blast to combustion.

2.—If an indicator is not used to determine pressure of steam in a cylinder, a safe estimate of it, when acting expansively, is .9 of full pressure, and when at stroke from .75 to .8.

Condensing. $\dfrac{A\,\overline{P^* - f\dagger}\; 2\,s\,r}{33\,000} = \text{HP}.$

Power required to work the air-pump of an engine varies from .7 to .9 lbs. per sq. inch upon cylinder piston.

ILLUSTRATION.—Diameter of cylinder of a marine steam-engine is 60 ins., stroke of piston 10 feet, revolutions 15 per minute, pressure of steam 50 lbs. per sq. inch, cut off at .25 stroke, and clearance 2 per cent.

$A = 2827.4$ *sq. ins.* P (per Ex., page 713) $= 28.62$ *lbs.* $f = 1.5 + \overline{28.62 - 1.5} \times .$ $= 2.467$ *lbs.*

$$\text{Then } \frac{2827.4 \times \overline{28.66 - 2.856} \times 2 \times 10 \times 15}{33\,000} = 662.23 \text{ HP}.$$

From which is to be deducted in marine engines power necessary to discharge water of condensation at level of load-line, which is determined by pressure due elevation of water, area of air-pump piston, and velocity of its discharge in feet per second.

Indicated. $\dfrac{A\,P\,2\,s\,r}{33\,000} = \text{HP}$, and $\dfrac{33\,000\,\text{HP}}{P\,2\,s\,r} = A.$

British Admiralty Rule.—*Nominal.* $\dfrac{7\,A\,v}{33\,000}$ or $\dfrac{D^2 v}{6000} = \text{HP}.$

French.—(*Force de Cheval.*) $1.695\,D^2\,L\,r = \text{HP}.$ D *and* L *in meters.*

ILLUSTRATION.—Assume a diameter of cylinder of .254 meters, with a stroke of piston of .3 meters and 250 revolutions per minute.

$$1.695 \times .254^2 \times .3 \times 250 = 8.18 \text{ HP}.$$

A *Force de Cheval* = 4500 kilometers per minute = 32 549 *foot-lbs.* = .98757 HP.

One HP = 1.0139 *Force de Chevaux.*

Compound Indicated. $A\,L\,r\left(\dfrac{P}{R''}\,\overline{1 \text{ hyp. log. } R''} - b\right).000053 = \text{HP}$

L *representing length of stroke in feet,* R″ *combined ratio of both cylinders, and* b *back pressure.*

ILLUSTRATION.—Assume area of cylinder 3 sq. ins., stroke 6 feet, one stroke of piston, and steam 60 lbs. per sq. inch, cut off at .25.

$A = 3$ *sq. ins.*, $L = 6$ *feet*, $n = 1$ *stroke*, $P = 60$ *lbs.*, $R'' = 5.969$, $b = 3$ *lbs. per sq. inch*, and $r = .5$, and $1 + \text{hyp. log. } R'' = 1 + 1.7865$.

Then $3 \times 6 \times .5 \times \left(\dfrac{60}{5.969} \times \overline{1 + 1.7865} - 3\right) \times .000053 = 9 \times \overline{10.052 \times 2.7865 - 3}$ $\times .000053 = .0132$ HP, which, $\times\, 2$ for 1 revolution, $= .0264$ HP *per revolution.*

To Compute Volume of Water required to be Evaporated in an Engine.

Multiply volume of steam expended in cylinder and steam-chest by number of revolutions, and multiply product by density of steam

* See 1st and 2d foot-note on previous page.

PLE.—What volume of water will an engine require to be evaporated per on, diam. of cylinder being 70 ins., stroke of piston 10 feet, and pressure of 4 lbs. per sq. inch, including atmosphere, cut off at .5 of stroke?

of cylinder $= 3848.5$ *ins.* $10 \times 12 \div 2 = 60$ *ins.*, $60 \times 3848.5 = 230910$ *cube ins.*

for clearance at one end, volume of nozzle, steam-chest, etc., 17 317 *cube ins.*

$230910 + 17317 \div 1728 \times 2 = 287.3$ *cube feet*, which, $\times .001\,336$, density of t 34 lbs. pressure (see Note 2), $= .3838$ *cube feet.*

I.—This refers to expenditure of steam alone; in practice, however, a large y of water "foaming," differing in different cases, is carried into cylinder in ation with the steam; to which is to be added loss by leaks, gauges, etc.

olume of steam is readily computed by aid of table, pp. 708–9. Thus, den- weight of one cube foot of steam at above pressure $= .0835$ lbs. Hence, as . : 1 *cube foot* :: .0835 *lbs.* : .001 336 *cube foot.*

ompute Volume of Circulating Water required by an Engine.

$\dfrac{+ .3\,T - t}{' - t''} = V.$ T *representing temperature of steam upon entering the con-* *t, t', and t'' temperatures of feed water, of water of condensation discharged, circulating water, all in degrees.*

STRATION.—Assume exhaust steam at 8 lbs. per sq. inch, temperatures of dis- 100°, feed water 120°, and sea-water 75°.

erature at 8 lbs. pressure $= 183°$. $\dfrac{1114 + .3 \times 183 - 120}{100 - 75} = 41.95$ *times.*

ompute Volume of Flow through an Injection Pipe.

E.—Multiply square root of product, of 64.33 and depth of centre of g into condenser, from surface of external water, added to height of a n of water due to vacuum in condenser, all in feet, by area of opening ins.; and .6 product, divided by 2.4 $(144 \div 60)$ will give volume in eet per minute.

MPLE.—Diameter of an injection pipe is 5.375 ins., height of external water condenser 6.13 feet, and vacuum 24.45 ins.; what is volume of flow per min.?

of 5.375 ins. $= 22.69$ ins., $c = .6$. Vacuum $\dfrac{24.45 \text{ ins.}}{2.04} = 12$ lbs.; 12×2.24 a-water) $= 26.88$ feet, and $26.88 + 6.13 = 33.1$ *feet.*

$$\text{Then } \frac{\sqrt{64.33 \times 33.1} \times 22.69 \times .6}{2.4} = \frac{628.15}{2.4} = 261.73 \textit{ cube feet.}$$

To Compute Area of an Injection Pipe.

LE.—Ascertain volume of water required by rule, page 706, in cube ins. econd, multiply it by number of volumes of water required for con- tion, by rule, page 707, divide it by velocity due to flow in feet per d, and again by 12, and quotient will give area in sq. ins.

MPLE.—An engine having a cylinder 70 ins. diam., stroke of piston 10 feet, tions per minute 15, and steam 19.3 lbs., mercurial gauge cut off at .5; what l be area of its injection pipe at its maximum operation?

ume of cylinder 267.25 cube feet, cut off at $.5 = 133.625$ *ins.*
sity of steam at 34 lbs. $(19.3 + 14.7) = .001\,336$. Velocity of flow of injected (computed from vacuum and elevation of condensing water) 33 feet per second.

1 $133.625 \times 15 \times 2 \times 1728 \div 60 = 115452$ *cube ins.* *second,* and
$\times .001\,336 = 154.24$ *cube ins. water per second.*

imum volume of water required to condense steam \
evaporated, which only occurs in the Gulf of Mexic
t 40 times.

$+ 11.59$ (*= 7.5* per cent. for leakage of valves, etc.
$= 11\,608.1$ *cube ins.*, and $11\,608.1 \div \overline{33 \times 12} = 29.31$

Coefficient of velocity for flow under like conditions = .6; hence, 29.3 ÷ 48.85 *sq. ins.*

NOTE.—This is required capacity for one pipe. It is proper and customary there should be two pipes, to meet contingency of operation of one being arre

To Compute Area of a Feed Pump. (*Sea-water.*)

RULE.—Divide volume of water required in cube ins. by number of strokes of piston, both per minute, and divide quotient by stroke of pu ins.; multiply this quotient by 6 (for waste, leaks, "running up," etc.) product will give area of pump in sq. ins.

EXAMPLE.—Assume volume to be 5 cube feet and revolutions of engine minute, with a stroke of pump of 3.5 feet.

$$\frac{5 \times 1728}{15} = 576, \text{ which} \div \overline{3.5 \times 12} = 13.72, \text{ and } 13.72 \times 6 = 82.32 \textit{ sq. ins}$$

NOTE.—In fresh water, this proportion may be reduced one half.

STEAM-INJECTOR. William Sellers & Co.

Self-adjusting.

Volume of Water Discharged per Hour.

No.	Pressure of Steam in Lbs.				No.	Pressure of Steam in Lbs.			
	60	80	100	120		60	80	120	[illegible]
	Cub. feet.	Cub. feet.	Cub. feet.	Cub. feet.		Cub. feet.	Cub. feet.	Cub. feet.	C[illegible]
3	28.12	31.66	35.2	38.75	7	162.65	182.1	201.55	[illegible]
4	52.16	58 44	64.72	71	8	213.2	238.8	264.4	[illegible]
5	82 18	92.02	101.86	111.7	9	269.97	302.28	334.59	[illegible]
6	119.09	133.33	147.57	161.82	10	333.64	373.57	413.49	[illegible]

Highest temperature admissible of feed water 135°.

To Compute Size of Injector required.

One IP per hour will require from 15 to 40 lbs. of water per hour, a ing to character of engine.

When the lbs. of coal burned per hour can be ascertained, divide th 7.5, and quotient will give the volume of water in cube feet per hour.

When the area of grate-surface is known, multiply it by 1.6 for IP.

In case of plain cylindrical boilers, divide the number of sq. feet of ing-surface by 10 for the IP. In case of flue boilers, divide by 12, and multi-tubular boilers, by 15, for the nominal IP.

Minimum capacity of Injectors, about 50 per cent. of Tabular capaci

To Compute Volume of Injection Water required IHP per Hour.

OPERATION.—Assume temperature of water 80°, and of condensation 100°. ume of cylinder per IHP as per formula, page 716, and illustration, page 717, feet per minute.

Then, as per rule page 707, $\frac{1146.1 - 100}{100 - 80} = 52.3$ *cube ins. per cube foot of stea*

$$\frac{2.76 \times 52.3 \times 62.5}{1728} = 5.22 \textit{ lbs.}, \text{ which}, \times 60, = 313.2 \textit{ lbs.}$$

To Compute Net Volume of Feed Water required IHP per Hour.

elements of formula, page 716, and illustration, page 7

Then $1154 \times 2.76 \times 60 = 19.11$ *lbs.*

= diameter for small, and $\frac{d}{32}\sqrt{v}$, for large pum

n ins., and v its velocity in feet per min

:esults of Operations of Steam-engines. (*D. K. Clark.*)

Condensing Engine.		Actual Ratio of Expansion.	Steam per IHP as cut-off.	Coal per IHP.	Initial Pressure at cut-off.	Steam per IHP per hour.
SINGLE.			Lbs.	Lbs.	Lbs.	Lbs.
iss, Saltaire		5.2	14.51	2.5	34.5	17.4
ping, Crossness		6.07	14.27	2.2	46	18.7
' East London		3.62	12.92	—	23.25	20.72
er, Corliss valves		10	—	3.3	50	19.6
:rheated, Hirn		4.132	—	—	60	18.62
COMPOUND.						
lder & Co.	Receiver	1.85	14.45	1.61	56	—
	Marine, jacketed	1.852	14.85			
E. Wood	Receiver	4.01	10.94	2.14	85.5	—
	stationary	1.857	13.34			
kin	Woolf, stationary	2.486	13.18	—	50.5	—
	jacketed	3.221	13.87	—	—	22.51
:rican, Woolf	1st cylinder	2.31	actual	—	90	15.37
	both	5.63	23.21			
" " jacketed	1st cylinder	3.77	20.71	—	90	14.1
	both	9.19				
NON-CONDENSING.						
shall, Sons, & Co.		4.8	16.87	—	76	25.9
ey, Paxman, & Co.		5	14.93	—	73	29.6
:motive "Great Britain"		1.45	31.36	—	102	31.36
" " "		2.94	21.24	—	87	21.24

'ractical Efficiency of Steam-engines. *Initial Volume = 1.*

Cylinders.	Most Efficient Ratio of Expansion.	Steam* per IHP per hour.	Cylinders.	Most Efficient Ratio of Expansion.	Steam* per IHP per hour.
CONDENSING.		Lbs.			Lbs.
le cylinder, jacketed	6	19.5	Compound, jacketed, Woolf	10	20.5
le cylinder	4	24	Compound, Woolf	7	23
" superheated	4	18.5	NON-CONDENSING.		
pound, jacketed, Re-iver	6	19	Single cylinder,† jacketed	4	24
			Single cylinder,‡	3	21

* From boiler. † 70 lbs. pressure. ‡ 90 lbs. pressure.

Standard Operation of a Portable Engine.

ɘ	5.5	sq. feet.
ing surface	220	" "
per IP per hour	6.25	lbs.
" sq. foot of grate	9	"
" hour	50	"
Water evaporated from and at 212° per hour	450	lbs.
" " per IP per hour	62.5	"
" " " sq. foot of grate	81.8	"

Ratio of heating surface of grate........ 40 to 1.

MIXTURE OF AIR AND STEAM.

ater contains a portion of air or other uncondensable gaseo converted into steam, this air is mixed with it, and when left in a gaseous state. If means were not taken to remov -er from condenser of a steam-engine, it would fill it and cy operation; but, notwithstanding the ordinary means of r p), a certain quantity of it always remains in condenser.

volumes of water absorb 1 volume of air.

ELEMENTS AND CAPACITIES OF DIRECT-ACTING STEAM-PUMPS.

-acting Steam-pumps have an especial advantage in the supplying of boilers or in the discharge of fluids, as their speed in continuously, and to maintain the water at a uniform height, level, or depth.

The Worthington Steam-pump.

Fire and General Service, having Two Double-acting Plungers.

Diameter of Water-plungers.	Length of Stroke.	Displacement in Gallons per Stroke of *one* Plunger.	Proper Strokes per Minute of *one* Plunger, varying with kind of Work and Pressure.	Volume delivered per Minute by *both* Plungers at stated Number of Strokes.	Diameter of Plunger required in any single Cylinder Pump for like Volume and Speed.	*Diameter of Pipes for Short Lengths.* To be increased as length increases. Steam-pipe.	Exhaust-pipe.	Suction-pipe.	Discharge-pipe.
Ins.	Ins.	Gallons.	No.	Gallons.	Ins.	Ins.	Ins.	Ins.	Ins.
2	3	.04	100 to 250	8 to 20	2.875	.375	.5	1.25	1
2.75	4	.1	100 to 200	20 to 40	4	.5	.75	2	1.5
3.5	5	.2	100 to 200	40 to 80	5	.75	1.25	2.5	1.5
4	6	.33	100 to 150	70 to 100	5.625	1	1.5	3	2
4.5	10	.69	75 to 125	100 to 170	6.375	1.5	2	4	3
5.25	10	.93	75 to 125	135 to 230	7.5	2	2.5	4	3
6	10	1.22	75 to 125	180 to 300	8.5	2	2.5	5	4
7	10	1.66	75 to 125	245 to 410	0.875	2.5	3	6	5
7	10	1.66	75 to 125	245 to 410	9.875	2.5	3	6	5
8.5	10	2.45	75 to 125	365 to 610	12	2.5	3	6	5
8.5	10	2.45	75 to 125	365 to 610	12	2.5	3	6	5
8.5	10	2.45	75 to 125	365 to 610	12	2.5	3	6	5
8.5	10	2.45	75 to 125	365 to 610	12	3	3.5	6	5
10.25	10	3.57	75 to 125	530 to 890	14.25	2.5	3	8	7
10.25	10	3.57	75 to 125	530 to 890	14.25	2.5	3	8	7
10.25	10	3.57	75 to 125	530 to 890	14.25	2.5	3	8	7
10.25	10	3.57	75 to 125	530 to 890	14.25	3	3.5	8	7
12	10	4.89	75 to 125	730 to 1220	17	2.5	3	10	8
12	10	4.89	75 to 125	730 to 1220	17	2.5	3	10	8
12	10	4.89	75 to 125	730 to 1220	17	3	3.5	10	8
14	10	6.66	75 to 125	990 to 1660	19.75	3	3.5	12	10
10	15	5.1	50 to 100	510 to 1020	14	3	3.5	10	8
12	15	7.34	50 to 100	730 to 1460	17	4	6	10	10

BOILER.

efficiency is determined by proportional quantity of heat of com-
›n of fuel used, which it applies to the conversion of water into
, or it may be determined by weight of water evaporated per lb.
:l.

·llowing results and computations, water is held to be evaporated from stand-
nperature of 212°.

ortion of surplus air, in operation of a furnace, in excess of that which is
:ally required for combustion of the fuel, is diminished as rate of combustion
eased; and this diminution is one of the causes why the temperature in a
; is increased with rapidity of combustion.

en combustion is rapid, some air should be introduced in a furnace
the grates, in order the better to consume the gases evolved.

Natural Draught.

te (*Coal*) should have a surface area of 1 sq. foot for a combustion of
. of coal per hour, length not to exceed 1.5 times width of furnace, and
an inclination toward bridge-wall of 1 to 1.5 ins. in every foot of length.

en, however, rate of combustion is not high, in consequence of low ve-
of draught of furnace, or fuel being insufficient, this proportion of area
be increased to one sq. foot for every 12 lbs. of fuel.

lth of bars the least practicable, spaces between them being from .5 to
an inch, according to fuel used. Anthracite requiring less space than
inous. Short grates are most economical in combustion, but generate
less rapidly than long.

el of grate under a plain cylindrical boiler gives best effect with a fire
deep, when grate is but 7.5 ins. from lowest point.

·th, Cast-iron, .6 square root of length in ins.

›od), their area should be 1.25 to 1.4 that for coal.
›matic (Vicar's).—Its operation effects increased rapidity in firing
ore effective evaporation.

-pit.—Transverse area of it, for a combustion of 15 lbs. of coal per
: to .25 area of grate surface for bituminous coal, and .25 to .3 for
cite. Or 15 to 20 ins. in depth for a width of furnace of 42 ins.

zace or Combustion Chamber.—(*Coal*) Volume of it from 2.75 to 3 cube
r sq. foot of grate surface. (*Wood*) 4.6 to 5 cube feet.
higher the rate of combustion the greater the volume, bituminous
:quiring more than anthracite. Velocity of current of air entering
-pit may be estimated at 12 feet per second.

me of air and smoke for each cube foot of water converted into steam is,
›al, 1780 to 1950 cube feet, and for wood, 3900.

: *of Combustion.*—In lbs. of coal per sq. foot of grate per hour.
h Boilers, slowest, 4; ordinary, 10. *Stationary*, 12 to 16. *Marine*,
:4. Quickest: complete combustion of dry coal, 20 to 23; of caking
4 to 27; *Blast or Fan and Locomotive*, 40 to 120.

lge-wall (*Calorimeter*).—Cross-section of an area of 1.[illegible] sq. ins.
:h lb. of bituminous coal consumed per hour, or fro[illegible] [illegible]n. ins.
:h sq. foot of grate, for a combustion of 15 lbs. of co[illegible]

ıperature of a furnace is assumed to range from [illegible]
› of air required for combustion of 1 lb. of bitu[illegible]
›oducts of combustion, is 154.81 cube feet, whic[illegible]
›mperatures, makes volume of heated air at bridg[illegible]
› feet for each lb. of coal consumed upon grate.

Hence, at a velocity of draught of about 12 feet per second, area ... wall, required to admit of this volume being passed off in an hour, is ... sq. ins., and proportionately for increased velocity, but in practice it ... 1.2 to 1.6 ins.

When 20 lbs. of coal per hour are consumed upon a sq. foot of grate ... 1.6 = 24 or 32 sq. ins. are required, and in a like proportion for other quantities.

Or, When area of flues is determined upon, and area over bridge-wall required, it should be taken at from .7 to .8 area of lower flues for a ... draught, and from .5 to .6 for a blast.

When one half of tubes were closed in a fire-tubular marine boiler, the evaporation per lb. of coal was reduced but 1.5 per cent.

Firing.—Coal of a depth up to 12 ins. is more effective than at a ... depth. Admission of air above the grate increases evaporative effect ... diminishes the rapidity of it.

Air admitted at bridge-wall effects a better result than when admitted ... door, and when in small volumes, and in streams or currents, it arrests or prevents smoke. It may be admitted by an area of 4 sq. ins. per sq. foot of grate.

Combustion is the most complete with firings or charges at intervals ... from 15 to 20 minutes.

With a fuel economizer (Green's) an increased evaporative effect of 9 per cent. has been obtained.

When external flues of a Lancashire boiler were closed, evaporative power ... slightly increased, but evaporative efficiency was decreased; and when 25 per ... of like surface in setting of a plain cylindrical boiler was cut off, evaporation ... reduced but 1.5 per cent. When temperature at base of chimney was 630°, with fire 12 ins. in depth, it was decreased to 556° with one 9 ins. in depth, and to ... with one 6 ins.

High wind increases evaporative effect of a furnace.

Stationary or *Land.*—Set at an inclination downward of .5 inch in 10 ...

Smoke Preventing.—A test of C. Wye Williams's design of preventing smoke ... Newcastle, 1857, as reported by Messrs. Longridge, Armstrong, and Richardson, gave an increased evaporative effect with the "practical prevention of smoke." Hence it was concluded, "That by an easy method of firing, combined with ... admission of air in front of furnace, and a proper arrangement of grate, emission of smoke may be effectually prevented in ordinary marine multi-tubular boilers with suitable coals. 2d. That prevention of smoke *increases* economic value of ... and evaporative power of boiler. 3d. That coals from the Hartley district have evaporative power fully equal to that of the best Welsh steam-coals."

Heating Surfaces.

Marine (*Sea-water*).—Grate and heating surfaces should be increased about .07 over that for fresh water.

Relative Value of Heating Surfaces.

Horizontal surface above the flame	= 1	Horizontal beneath the flame	= ...
Vertical	= .5	Tubes and flues	= ...

Minimum Volumes of Fuel Consumed per Sq. Foot of Grate per Hour, for given Surface-ratios. (*D. K. Clark.*)

...cription of Boiler.	10	15	20	30	40	50	60	75	90	[illegible]
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	[illegible]
...ry...		1.7	3	6.8	12.1	18.9	26	—	—	-
		.6	2.8	6.3	11.2	17.5	24	—	—	-
		4	.8	1.8	3.2	5	—	—	—	-
		-	1.3	2.9	5.2	8.1	11.7	18.3	26.3	[illegible]
			1.8	4	7	11	16	25	36	[illegible]

...of fuel (120 lbs.) coke will withstand disturbing ...

ıle of sediment one sixteenth of an inch thick will effect a loss of 14.7 per ' fuel.

sq. foot of *fire* surface is held to be as effective as three of *heating.*

Relation of Grate, Heating Surface, and Fuel.

ən Grate and Heating Surface are constant, greater the weight of fuel ned per hour, greater the volume of water evaporated; but the volume decreased proportion to fuel consumed.

eating of relations of grate, surface, and fuel, D. K. Clark, in his valuable ;, submits, that in 1852 he investigated the question of evaporative perform- ' locomotive-boilers, using coke; and he deduced from them, that, assuming ant efficiency of fuel, or proportion of water evaporated to fuel, evaporative ›r volume of water which a boiler evaporates per hour, *decreases* directly as rea is increased; that is to say, larger the grate, less the evaporation of water, ə rate of efficiency of fuel, even with same heating surface.

'hat evaporative effect *increases* directly as square of heating surface, with rea of grate and efficiency of fuel.

Iecessary heating surface *increases* directly as square root of effect—viz., for nes effect, with same efficiency, twice heating surface only is required.

Necessary heating surface *increases* directly as square root of grate, with same cy; that is, for instance, if grate is enlarged to four times its first area, twice ; surface would be required, and would be sufficient, to evaporate same vol- ' water per hour with same efficiency of fuel.

ult of 40 experiments with a stationary boiler (fresh water), with an :ation of 9 lbs. water per lb. of fuel consumed, the coefficient .002 22 əduced.

ce, $\left(\frac{h}{g}\right)^2 .002\,22 = W$. W *representing volume of water in cube feet, and g areas of grate and heating surfaces in sq. feet.*

STRATION.—Assume a heating surface of 90 feet, and a grate of 3; what will evaporation?

$$\text{Then } \overline{90 \div 3}^{\,2} \times .002\,22 = 1.998 \textit{ cube feet.}$$

E.—A Galloway stationary boiler, with a ratio of grate area of 34.3 and a con- ion of 21.8 lbs. coal per hour, evaporated 2.9 cube feet of water per sq. foot of Hence the coefficient in this case would be .002 466.

Compute Areas of Grate and Heating Surfaces, Volume of Water, and Weight of Fuel.

For a Temperature of 281°, or Pressure of 50 lbs. per Sq. Inch.

To Compute Weight of Fuel.

Water per Sq. Foot of Grate per Hour and Surface Ratio are Given.

$$\frac{W - x\,R^2}{C} = F, \text{ and } x\,R^2 = (E - C)\,F.$$

STRATION.—Assume elements as preceding.

$$\frac{200 - \overline{.02 \times 50^2}}{10} = 15, \text{ and } .02 \times 50^2 = \left(\frac{200}{15} - 10\right) \times 15 = 50.$$

Compute Ratio of Heating Surface to Area of Grate, and to Effect a Given Evaporation.

ən *Water and Fuel per Sq. Foot of Grate are Given.* $\sqrt{\frac{W - C\,F}{x}} = R.$

esenting water evaporated per sq. foot of grate, and F *fuel consumed, both per hour.* C *and x specific constants for each type of boiler, and* R $(h \div g)$ *heating surface to grate.*

STRATION.—Assume W = 200, C = 10, F = 15, and

$$\frac{\overline{00 - 10 \times 15}}{.02} = 50; \quad \frac{200 - .02 \times 50^2}{10} = 15; \text{ and ,}$$

When Efficiency of Fuel and Fuel consumed per Sq. Foot of Grate per Hour are given. $\frac{W}{F} = E$ or *efficiency of fuel or weight of water evaporated per lb. of fuel.* $\sqrt{\frac{(E-C)\,F}{x}} = R$.

To Compute Fuel that may be consumed per Sq. Foot of Grate per Hour, corresponding to a Given Efficiency.

When Efficiency of Fuel, that is, Weight of Water evaporated per lb. of Fuel, and the Surface Ratio, are given.

$$\frac{x\,R^2 + C\,F}{F},\quad C + \frac{x\,R^2}{F} = E, \text{ and } \frac{x\,R^2}{E - C} = F.$$

ILLUSTRATION.—Assume elements as preceding.

$$\frac{.02 \times 50^2 + \overline{10 \times 15}}{15} = 13.33;\quad 10 + \frac{.02 \times 50^2}{15} = 13.33, \text{ and } \frac{.02 \times 50^2}{13.33 - 10} = 15 \text{ lbs.}$$

Combustion of Coal per sq. foot of grate.—*Natural Draught*, from 20 to 25 lbs. may be consumed per hour.—*Steam-jet*, 30 lbs., and *Exhaust-blast* 65 to 80 lbs.

From Results of Experiments upon Marine Boilers, see Manual of D. K. Clark, page 808; he deduced the following formula, as applicable to all surface ratios in such boilers.

Newcastle $.02156\,R^2 + 9.71\,F$, and for Wigan $.01\,R^2 + 10.75\,F = W$ in lbs.

And the general formulas he deduced from all the various experiments are as follows.

From and at 212°.

Portable...... $.008\,R^2 + \overline{8.6\ F} = W$	Marine........... $.016\,R^2 + \overline{10.25\,F} = W$
Stationary... $.0222\,R^2 + \overline{9.56\,F} = W$	Locomotive, coal, $.009\,R^2 + \overline{9.7\,F} = W$

Locomotive, coke......... $.0178\,R^2 + \overline{7.94\,F} = W$.

As the maximum evaporative power of fuel is a fixed quantity, the preceding formulas are not fully applicable in minimum rates of its consumption and evaporative quality.

With coal and coke the limits of evaporative efficiency may be taken respectively at 12.5 and 12 lbs. water from and at 212°.

ILLUSTRATION 1.—Assume a marine fire-tubular boiler with a surface ratio of heating surface to grate of 30 and a consumption of coal of 15 lbs. per sq. foot of grate per hour, what will be its evaporation per sq. foot of grate?

$$.016 \times 30^2 + \overline{10.25 \times 15} = 168.15 \textit{ lbs.}$$

2.—Assume a like boiler, using fresh water, to have a ratio of heating surface to grate of 30 and an evaporation of 165 lbs. water per sq. foot of grate per hour, what would be consumption of coal per sq. foot of grate per hour?

$$\frac{165 - \overline{.016 \times 30^2}}{10.25} = 14.69 \textit{ lbs.}$$

Tube Surface (*Iron*) per lb. of coal 1.58, per sq. foot of grate 32, and per IHP ... sq. feet.

Locomotive Boiler has from 60 to 90 sq. feet per foot of grate, and consumes ... lbs. coal per sq. foot per hour.

Evaporative Capacity of Tubes of Varying Length.

Total Length of Tubes 12 Feet 3 ins. (*M. Paul Hevrer, 1874.*)

SURFACE AND WATER.	Furnace and 3 ins. in Length of Tubes.	TUBES. 3.02 Feet.	3.02 Feet.	3.02 Feet.	[illegible]
Surface in sq. feet..............	76.43	179	179	179	[illegible]
Water evaporated per sq. foot per hour in lbs.....	24.5	8.72	4.42	[illegible]	[illegible]

...ults of Operation of Boilers under Varying Proportions of Grate, Area, and Length of Heating Surface, Draught of Furnace, and Rate of Combustion.

Description.	Area of Grate.	Heating Surface.	Grate to Heating Surface.	Coal per Sq. Foot of Grate per Hour.	Evaporation of Water from 212°, per sq. ft. of grate.	Evaporation of Water from 212°, per lb. of Coal.	Fuel.
Fire-tubular.	Sq. Feet.	Sq. Feet.	Ratio.	Lbs.	Lbs.	Lbs.	
...ultural and Hoisting	4.7	158	34	13	119	9.33	Welsh.
" " "	3.2	220	69	12.8	151	11.83	"
...motive............ }	{ 26.25	963.5	36.7	30.86	327	10.6	"
...sh................ }	{ 16	818	51	38	375	10.47	"
....	10.5	788	75	45	419	11.04	"
....	10.6	1056	100	157	1401	10.41	"
...ne 1	22	748	34	24.3	265	10.7	"
1	18	749	41.6	23.6	264	11.2	"
2	10.3	915	50	41.25	468	11.36	"
2*	10.3	508	49.3	27.63	309.8	11.54	Lanc'r
3	10.8	151.2	14	27.76	205	7.39	Anth'e
...onary 4.............	31.5	945	30	28.87	293.7	10.17	Welsh.
" 2.............	31.5	767	24.4	14	141.4	10.1	"

1 New Castle. 2 and 4 Wigan. 3 Experimented at New York.

...fect of reducing the tube-surfaces was tried by stopping one half the number of tubes in alter...agonal rows, so that the tube surface was reduced 206.5 sq. feet. The results with fires 12 ins. ...ere as follows:

	Tubes open.	Tubes half closed.
Coal per sq. foot of grate per hour	25 lbs.	24 lbs.
Water from 212° per lb. of coal......................	12.41 "	12.23 "
Smoke per hour, very light..........................	2.8 minutes.	8 minutes.

...aporative Effects of Boilers for Different Rates of Combustion, and Surface Ratios. (*D. K. Clark.*)

Water from and at 212° per Hour.

Surface Ratio 30.

...per ...oot ...ate ...our.	Stationary. Water per Sq. foot.	Stationary. Water per lb. of Coal.	Marine. Water per Sq. foot.	Marine. Water per lb. of Coal.	Portable. Water per Sq. foot.	Portable. Water per lb. of Coal.	Locomotive. Coal. Water per Sq. foot.	Locomotive. Coal. Water per lb. of Coal.	Locomotive. Coke. Water per Sq. foot.	Locomotive. Coke. Water per lb. of Coal.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
	116	11.6	117	11.7	93	9.3	105	10.5	95	9.5
	163	10.9	168	11.2	136	9	154	10.3	135	9
	211	10.6	219	10.9	179	9	202	10.1	175	8.7
	307	10.2	322	10.7	265	8.8	299	10	254	8.5

Surface Ratio 50.

	187	12.5	187.5	12.5	149	9.9	168	11.2	164	10.9
	247	12.3	248	12.5	192	9.6	217	10.9	203	10.2
	342	11.4	348	11.6	278	9.3	314	10.4	283	9.4
	438	10.9	450	11.3	364	9.1	411	10.3	362	9
	534	10.7	552	11	450	9	508	10.1	442	8.8

Surface Ratio 75.

	Water.	Fuel per Sq. Foot of Grate per Hour in Lbs. 30	40	50	60	75	90	100
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
...motive, coal..	Per sq. foot.	342	439	536	633	778	927	1020
" " ..	" lb. coal.	11.4	11	10.7	10.7	10.4	10.3	10.2
" coke .	" sq. foot.	338	418	497	576	695	815	894
" " ..	" lb. coal.	11.3	10.4	9.9	9.6	9.3	9	8.9

...hen a heater is used, and temperature of feed-water is raised above that of ...d in a condensing engine, the proportions of surfaces may be correspondingly ...ed.

Results of Operation of various Designs of Boiler, u der varying Proportions of Grate, Calorimeter, A and Length of Heating Surface, Draught, Firing, a Rate of Combustion.

STATIONARY.	Area of Grate.	Heating Surface.	Grate to Heating Surface.	Circuit of Heating Surface.	Temperature of Chimney.	Coal per Sq. Foot of Grate per Hour.	Water Evapo[rated] from 212° per lb. of Coal.	per S[q.] … of … per …
	Sq. Ft.	Sq. Ft.	Ratio.	Feet.	°	Lbs.	Lbs.	[illegible]
Lancashire double internal and external flued[1]...	20.5	612	29.8	79	511	15.35	8.32	[illegible]
" " [2]......	21	767	36.5	80	505	21.5	10.88	[illegible]
Galloway vertical water-tubular[2].	21	719	22.8	79	505	22.7	10.77	[illegible]
" " [2]...	31.5	719	34.3	80	630	18.3	10.17	[illegible]
Fairbairn[1].........	20.5	1017	49.5	—	387	15.27	8.67	[illegible]
French[1]...........	20.1	607	30.3	—	510	16.42	8.12	[illegible]
Cylindrical flued[3]...	14.2	377.5	26.8	56	292	7.43	9.08	[illegible]
MARINE.	*At Pressure of Atmosphere.*							
Horizontal fire-tub.[2]	10.3	508	49.3	—	—	27.5	11.92	[illegible]
" " [2]	10.3	508	49.3	—	—	41.25	11.36	[illegible]
" " [2]	10.3	302	30	—	—	24	12.23	[illegible]
" "	19.3	749	39	—	—	21	10	[illegible]
" "	28.5	749	26.3	—	—	21.15	8.94	[illegible]
" "	28.5	749	26.3	—	—	19	11.13	[illegible]
" " (C. Wye Williams)	15.5	749	48.3	—	600	37.4	10.63	[illegible]
" " / " "	22	749	34	—	600	17.27	11.7	[illegible]
" " / " "	42	749	17.6	—	—	16	9.65	[illegible]
" " [3]	10.8	150	13.9	8.5	—	10.99	8.95	[illegible]
" " [3]	4.32	147	34	8.5	—	27.58	7.24	[illegible]

[1] Trial in France. [2] At Wigan, 1866–68, height of chimneys 100 feet. [3] N… yard, Washington, U. S., chimney 61 feet. [4] At pressure of atmosphere, fires … deep, at 40 lbs. pressure, evaporation was reduced 12 per cent. [5] Bituminous … [6] Anthracite, at pressure of 6.5 lbs. above atmosphere. [7] Fires 14 ins. deep, a… mitted through furnace-doors. [8] Ditto do., jet blast. [9] Half tubes closed … [10] Air through grate only. [11] Air through grate and door, no smoke. [12] One … ing in door, temp. 625°, with two 633°, with four 638°, and with six 600°. [13] … grates, air spaces fully open, no smoke. [14] One furnace, anthracite coal, 5 ins. …

Draught.

Draught of Furnace.—Volume of gas varies directly as its absolute … perature, and draught is best when absolute temperature of gas in chi… is to that of external air as 25 to 12.

$\frac{T + 461.2°}{32° + 461.2°} = \frac{V}{V'} = V''$. V, V', *and* V'' *representing absolute temperatur… or temperature given, and at* 32°, *in degrees and volume of furnace gas at tem… ture* T *in cube feet.*

ILLUSTRATION.—Assume temperature of furnace or $T = 1500°$, and 12 lbs. … lb. of fuel.

$\frac{1500° + 461.2°}{32° + 461.2°} = 3.98$, *and as* 150 *cube feet is volume of gas per lb. of fu… lbs. supply of air*, $150 \times 3.98 = 597$ *cube feet.*

$\frac{W\,v\,t}{a\,V'} = C$. W *representing weight of fuel consumed in furnace per second, … v volume of air at* 32° *supplied per lb. of fuel in cube feet, t absolute tempera… gas discharged by chimney in degrees, a area of chimney in sq. feet, and* C *v… current in chimney in feet per second.*

ILLUSTRATION.—Assume W = .16, $v = 150$, $t = 1000°$, and $a = 5$.

$$\frac{.16 \times 150 \times 1000}{5 \times 493.2°} = \frac{24\,000}{2466} = 9.73 \textit{ feet.}$$

.084 to .087 = D. D *representing weight of a cube foot of gas discharged by* ...*ney, in lbs.* ILLUSTRATION. $\frac{493.2°}{1000} \times .086 = .0424$ *lb.*

$\frac{\ }{\ }\left(1 + G + \frac{f\,l}{m}\right) = H$. G *representing a coefficient of resistance and friction of* ...*through grate and fuel,* f coefficient of friction of gas through flues and over* ... *surfaces,† l length of flues and chimney, m hydraulic mean depth,‡ and* H *height* ...*imney, all in feet.*

ILLUSTRATION I.—Assume C = 9.73, $l = 60$, and $m = .72$, *all in feet.*

$$\frac{9.73^2}{64.33}\left(1 + 12 + \frac{.012 \times 60}{.72}\right) = \frac{94.67}{64.33} \times 14 = 20.6 \textit{ feet.} \qquad \frac{C\,a\,V'}{v\,t} = W.$$

—Assume preceding elements. $\frac{9.73 \times 5 \times 493.2°}{150 \times 1000} = .16$ *lb.*

...*hen* H *is given.* $\sqrt{\left(H\,2\,g \div 1 + G + \frac{f\,l}{m}\right)} = C$

ILLUSTRATION.—Assume preceding elements. $\sqrt{20.6 \times 64.33 \div 14} = 9.73$ *feet.*

...2 × pressure in lbs. per sq. foot = *head in ins. of water.*

...emperature at base of smoke-pipe or chimney, or termination of flues or ..., is estimated at 500°; and base of chimney, or its *calorimeter*, should ... an area of 1.3 to 1.6 sq. ins. for every lb. of coal consumed per hour. ... tubes of small diameter, compared to their length, this proportion may ...educed to 1 and 1.2 ins.

...dmission of air behind a bridge-wall increases temperature of the gases, ...it must be at a point where their temperature is not below 800°.

Loss of Pressure by Flow of Air in Pipes.

Length 3280 *Feet, or* 1000 *Meters.*

...city at Entrance of Pipe. Feet per Second.	Meter per Second.	4	6	8	10	12	14
		Diameter of Pipe in Ins. — Loss of Pressure in Lbs. per Sq. Inch.					
...28	1	.114	.076	.057	.057	.038	.038
...56	2	.5	.343	.25	.21	.172	.153
...84	3	1.183	.8	.592	.477	.394	.343
...12	4	2.06	1.374	1.03	.84	.687	.6
...4	5	3.2	2.16	1.61	1.29	1.1	.923
...68	6	4.446	2.964	2.223	1.778	1.482	1.28

... Mount Cenis Tunnel, the loss of pressure from 84 lbs. per sq. inch, in a pipe ...5 ins. in diameter and 1 mile 15 yards in length, was but 3.5 per cent.

Artificial Draught.

...n production of draught in an ordinary marine boiler, from 20 to 33 per ... of total heat of combustion of fuel is expended.

...ast.—By experiments of D. K. Clark and others it was deduced that the vacuum ...ack connection is about .7 of blast pressure, and in the furnace from .33 to .5 ...at in back connection; that rate of evaporation varies nearly as square root of ...uum in back connection; that best proportions of chimney and passages thereto ...those which enable a given draught to be produced with greatest diameter of ...-pipe; for the manifest reason, that the greater that diameter, the less the back-...ssure due to resistance of orifice, and that these proportions are best at all rates ...xpansion and speeds.

** Which, in furnaces consuming from 20 to 24 lbs. coal per sq. foot of grate per hour, is assigned ...at 12.* † *Estimated by same authority at .012*

‡ For a square or circular flue is .25 its diameter.

When Efficiency of Fuel and Fuel consumed per Sq. Foot of Grate [illegible] *are given.* [illegible] $= E$ [illegible] *of fuel or weight of water evaporated* [illegible] *of fuel.* [illegible] $= R$.

To Compute Fuel that may be consumed per Sq. Foot of Grate per Hour, corresponding to a Given [illegible].

When Efficiency of Fuel, that is, Weight of Water evaporated per lb. of Fuel, and the Surface Ratio are given.

[illegible] $= E$ and [illegible] $= F$

ILLUSTRATION.—Assume elements as preceding.

[illegible] and [illegible]

Combustion of Coal per sq. foot of grate.—*Natural Draught*, from [illegible] lbs. [illegible] per hour.—*Blast*, [illegible] lbs. and *Exhaust-blast* [illegible] lbs.

From Results of Experiments upon Marine Boilers, see Manual of [illegible] page [illegible] [illegible] surface [illegible]

[illegible] R^2 [illegible] F, and for W [illegible] $R^2 +$ [illegible] $F = W$ [illegible]

And the general formulas he deduced from all the various experiments [illegible]

From and at $212°$

Portable..... [illegible] $R^2 +$ [illegible] $F = W$ Marine.......... $.016 R^2 + 10.25 F =$ [illegible]
Stationary... $.0222 R^2 + 9.56 F = W$; Locomotive, coal. $.009 R^2 +$ [illegible] $F =$ [illegible]
Locomotive, coke........ [illegible] $R^2 + 7.54 F = W$.

As the maximum evaporative power of fuel is a fixed quantity, the preceding formulas are not fully applicable in maximum rates of its consumption and evaporative quality.

With coal and coke the limits of evaporative efficiency may be taken respectively at 12.5 and 12 lbs. water from and at 212°.

ILLUSTRATION 1.—Assume a marine fire-tubular boiler with a surface ratio of heating surface to grate of 30 and a consumption of coal of 15 lbs. per sq. foot of grate per hour, what will be its evaporation per sq. foot of grate?

$$.016 \times 30^2 + 10.25 \times 15 = 163.15 \ lbs.$$

2.—Assume a like boiler, using fresh water, to have a ratio of heating surface to grate of 30 and an evaporation of 165 lbs. water per sq. foot of grate per hour. What would be consumption of coal per sq. foot of grate per hour?

$$\frac{165 - .016 \times 30^2}{10.25} = 14.69 \ lbs.$$

[illegible]*face* (*Iron*) per lb. of coal 1.58, per sq. foot of grate 32, and per IP [illegible]

[illegible]*ler* has from 60 to 90 sq. feet per foot of grate, and consume[illegible] [illegible]ot per hour.

[illegible] Capacity of Tubes of Varying Length[illegible]

[illegible]*ngth of Tubes* 12 *Feet* 3 *ins.* (*M. Paul Havrez*, 1874.)

Furnace and [illegible]ns. in Length of Tubes.	3.02 Feet.	3.02 Feet.	3.02 Feet.	[illegible]
76.43	179	179	179	[illegible]
[illegible]4.5	8.72	4.42	[illegible]	[illegible]

lts of Operation of Boilers under Varying Propor- ns of Grate, Area, and Length of Heating Surface, aught of Furnace, and Rate of Combustion.

Description.	Area of Grate.	Heating Surface.	Grate to Heating Surface.	Coal per Sq. Foot of Grate per Hour.	Evaporation of Water from 212° per sq. ft. of grate.	Evaporation of Water from 212° per lb. of Coal.	Fuel.
Fire-tubular.	Sq. Feet.	Sq. Feet.	Ratio.	Lbs.	Lbs.	Lbs.	
tural and Hoisting	4.7	158	34	13	119	9.33	Welsh.
" "	3.2	220	69	12.8	151	11.83	"
›tive............ }	{ 26.25	963.5	36.7	30.86	327	10.6	"
.... }	{ 16	818	51	38	375	10.47	"
....	10.5	788	75	45	419	11.04	"
....	10.6	1056	100	157	1401	10.41	"
ɪ	22	748	34	24.3	265	10.7	"
ɪ	18	749	41.6	23.6	264	11.2	"
2	10.3	915	50	41.25	468	11.36	"
2*	10.3	508	49.3	27.63	309.8	11.54	Lanc'r
3	10.8	151.2	14	27.76	205	7.39	Anth'e
ary 4............	31.5	945	30	28.87	293.7	10.17	Welsh.
2	31.5	767	24.4	14	141.4	10.1	"

ɪ New Castle. 2 and 4 Wigan. 3 Experimented at New York.

t of reducing the tube-surfaces was tried by stopping one half the number of tubes in alter- ;onal rows, so that the tube surface was reduced 206.5 sq. feet. The results with fires 12 ins. e as follows:

	Tubes open.	Tubes half closed.
Coal per sq. foot of grate per hour	25 lbs.	24 lbs.
Water from 212° per lb. of coal	12.41 "	12.23 "
Smoke per hour, very light	2.8 minutes.	8 minutes.

›orative Effects of Boilers for Different Rates of Combustion, and Surface Ratios. (*D. K. Clark.*)

Water from and at 212° per Hour.

Surface Ratio 30.

Stationary. Water per Sq. foot.	Stationary. Water per lb. of Coal.	Marine. Water per Sq. foot.	Marine. Water per lb. of Coal.	Portable. Water per Sq. foot.	Portable. Water per lb. of Coal.	Locomotive. Coal. Water per Sq. foot.	Locomotive. Coal. Water per lb. of Coal.	Locomotive. Coke. Water per Sq. foot.	Locomotive. Coke. Water per lb. of Coal.
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
116	11.6	117	11.7	93	9.3	105	10.5	95	9.5
163	10.9	168	11.2	136	9	154	10.3	135	9
211	10.6	219	10.9	179	9	202	10.1	175	8.7
307	10.2	322	10.7	265	8.8	299	10	254	8.5

Surface Ratio 50.

187	12.5	187.5	12.5	149	9.9	168	11.2	164	[illegible]
247	12.3	248	12.5	192	9.6	217	10.9	203	[illegible]
342	11.4	348	11.6	278	9.3	314	10.4	283	
438	10.9	450	11.3	364	9.1	411	10.3	362	
534	10.7	552	11	450	9	508	10.1	442	

Surface Ratio 75.

	Water.	Fuel per Sq. Foot of Grate per Hour in Lb 30	40	50	60	75	90
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
›tive, coal..	Per sq. foot.	342	439	536	633	778	927
" ..	" lb. coal.	11.4	11	10.7	10.7	10.4	10.3
coke .	" sq. foot.	338	418	497	576	695	815
" ..	" lb. coal.	11.3	10.4	9.9	9.6	9.3	9

n a heater is used, and temperature of feed-water is raised above that in a condensing engine, the proportions of surfaces may be correspondingly d.

Results of Operation of various Designs of Boiler, der varying Proportions of Grate, Calorimeter, A and Length of Heating Surface, Draught, Firing, Rate of Combustion.

STATIONARY.	Area of Grate.	Heating Surface.	Grate to Heating Surface.	Circuit of Heating Surface.	Temperature of Chimney.	Coal per Sq. Foot of Grate per Hour.	Water Evapo… from 212° per lb. of Coal.	per S… of… per…
	Sq. Ft.	Sq. Ft.	Ratio.	Feet.	°	Lbs.	Lbs.	l
Lancashire double internal and external flued[1]...	20.5	612	29.8	79	511	15.35	8.32	1
" " [2]......	21	767	36.5	80	505	21.5	10.88	2
Galloway vertical water-tubular[2].	21	719	22.8	79	505	22.7	10.77	2
" " [2]...	31.5	719	34.3	80	630	18.3	10.17	1
Fairbairn[1].........	20.5	1017	49.5	—	387	15.27	8.67	1
French[1]...........	20.1	607	30.3	—	510	16.42	8.12	1
Cylindrical flued[3]...	14.2	377.5	26.8	56	292	7.43	9.08	
MARINE.	*At Pressure of Atmosphere.*							
Horizontal fire-tub.[2]	10.3	508	49.3			27.5	11.92	
" " [2]	10.3	508	49.3			41.25	11.36	
" " [2]	10.3	302	30			24	12.23	
" "	19.3	749	39			21	10	
" "	28.5	749	26.3			21.15	8.94	
" "	28.5	749	26.3			19	11.13	
" " (C. Wye Williams)	15.5	749	48.3		600	37.4	10.63	
" " / " "	22	749	34		600	17.27	11.7	
" " / " "	42	749	17.6			16	9.65	
" " [3]	10.8	150	13.9	8.		10.99	8.95	
" " [3]	4.32	147	34	8.		27.58	7.24	

[1] Trial in France. [2] At Wigan, 1866–68, height of chimneys 100 feet. [3] yard, Washington, U. S., chimney 61 feet. [4] At pressure of atmosphere. fires deep, at 40 lbs. pressure, evaporation was reduced 12 per cent. [5] Bituminou 6 Anthracite, at pressure of 6.5 lbs. above atmosphere. [7] Fires 14 ins. deep. mitted through furnace-doors. [8] Ditto do., jet blast. [9] Half tubes clos [10] Air through grate only. [11] Air through grate and door, no smoke. [12] On ing in door, temp. 625°, with two 633°, with four 638°, and with six 600°. grates, air spaces fully open, no smoke. [14] One furnace, anthracite coal, 5 in

Draught.

Draught of Furnace.—Volume of gas varies directly as its absolut perature, and draught is best when absolute temperature of gas in ch is to that of external air as 25 to 12.

$$\frac{T + 461.2^\circ}{+ 461.2^\circ} = \frac{V}{V'} = V''.$$ V, V′, *and* V″ *representing absolute temperatu* *ature given, and at* 32°, *in degrees and volume of furnace gas at* *be feet.*

ox.—Assume temperature of furnace or T = 1500°, and 12 lbs.

2° = 2.08, *and as* 150 *cube feet is volume of gas per lb. of fu*

= 597 *cube feet.*

ight of fuel consumed in furnace per second

lb. of fuel in cube feet, t absolute tempera *a area of chimney in sq. feet, and C* *d.*

STRATION.—Assume W = .16, $v = 150$, $t = 1000°$, and $a = 5$.

$$\frac{.16 \times 150 \times 1000}{5 \times 493.2°} = \frac{24\,000}{2466} = 9.73 \textit{ feet.}$$

84 to .087 = D. D *representing weight of a cube foot of gas discharged by y, in lbs.* ILLUSTRATION. $\frac{493.2°}{1000} \times .086 = .0424$ *lb.*

$1 + G + \frac{fl}{m}\Big) = H$. G *representing a coefficient of resistance and friction of ough grate and fuel,* f coefficient of friction of gas through flues and over urfaces,† l length of flues and chimney, m hydraulic mean depth,‡ and* H *height ney, all in feet.*

STRATION I.—Assume C = 9.73, $l = 60$, and $m = .72$, *all in feet.*

$$\frac{9.73^2}{64.33}\left(1 + 12 + \frac{.012 \times 60}{.72}\right) = \frac{94.67}{64.33} \times 14 = 20.6 \textit{ feet.} \qquad \frac{C\,a\,V'}{v\,t} = W.$$

Assume preceding elements. $\frac{9.73 \times 5 \times 493.2°}{150 \times 1000} = .16$ *lb.*

n H *is given.* $\sqrt{\left(H\,2\,g \div \overline{1 + G + \frac{fl}{m}}\right)} = C$

STRATION.—Assume preceding elements. $\sqrt{20.6 \times 64.33 \div 14} = 9.73$ *feet.*

× pressure in lbs. per sq. foot = *head in ins. of water.*

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nission of air behind a bridge-wall increases temperature of the gases, must be at a point where their temperature is not below 800°.

Loss of Pressure by Flow of Air in Pipes.

Length 3280 Feet, or 1000 Meters.

ty at Entrance of Pipe.		*Diameter of Pipe in Ins.*					
t ond.	Meter per Second.	4	6	8	10	12	14
		Loss of Pressure in Lbs. per Sq. Inch.					
8	1	.114	.076	.057	.057	.038	.038
6	2	.5	.343	.25	.21	.172	.153
4	3	1.183	.8	.592	.477	.394	.343
2	4	2.06	1.374	1.03	.84	.687	.6
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8	6	4.446	2.964	2.223	1.778	1.482	1.28

Mount Cenis Tunnel, the loss of pressure from 84 lbs. per sq. inch, in a pipe ns. in diameter and 1 mile 15 yards in length, was but 3.5 per cent.

Artificial Draught.

production of draught in an ordinary marine boiler, from 20 to 33 per of total heat of combustion of fuel is expended.

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---

ich, in furnaces consuming from 20 to 24 lbs. coal per sq. foot [illegible]
.t 12. † Estima[illegible]
a square or circular flue is .25 its diameter.

Proportions of Eyes of Stays, Rods, etc.

Dimensions	No. 1.	No. 2.	No. 3.
	Forged.	Upset and Welded.	Drilled from Bar.

No. 1. a and e = 1 inch.
b = .5 "
c = .75 "

No. 2. a and e = 1 "
b = .5 "
c = .75 "

No. 3. a and e = 1 "
b = .75 "
c = .625 "

When drilled from upset bar, dimensions same as for No. 1. [illegible] .66 neck of rod.

Stay-bolts.—*Iron*, are not to be subjected to a greater stress [illegible] 6000 lbs. per sq. inch of section; *Steel*, 8000 lbs., both stress computed [illegible] weakest part of rod, and when of steel they are not to be welded.

To Compute Diameter and Pitch of Stay-bolts, and Resistance they will Sustain.

Screwed. $\frac{p\sqrt{P}}{70} = d$, $\frac{d \cdot 70}{\sqrt{P}} = p$, and $\left(\frac{70\,d}{p}\right)^2 = P$. *Socket.* $\frac{p\sqrt{P}}{95} = d$, $\frac{d\,95}{\sqrt{P}} = p$, and $\left(\frac{95\,d}{p}\right)^2 = P$. *d representing diameter in ins.*

Illustration.—Assume pitch of stay bolts 6 ins., and working pressure [illegible] lbs. per sq. inch; what should be diameters of bolts, both screw and socket?

$$\frac{6 \times \sqrt{100}}{70} = .857 \text{ inch Screwed, and } \frac{6 \times \sqrt{100}}{95} = .63\tfrac{1}{2} \text{ inch Socket.}$$

Girders. (Lloyd's.)

$\frac{C\,d^2\,t}{(L - p)\,D\,L} = P$, $\frac{P\,(L - p)\,D\,L}{C\,d^2} = t$, $\sqrt{\frac{P\,(L - p)\,D\,L}{C\,t}} = d$. *L representing length of girder, d its depth, t its thickness at centre or sum of its thickness [illegible] distance apart from centre to centre, and p pitch of stays, all in ins., and C a co[illegible] as per following:*

One stay to each girder, C = 6000. If two or three = 9000. If four = 10200.

Illustration.—Assume triple stayed girder, 24 ins. in length, 3 ins. in depth, 1 inch thick, and stayed at intervals of 6 ins.; what working pressure will it sustain?

$$C = 9000. \text{ Then } \frac{9000 \times 6^2 \times 1}{(24 - 6) \times 6 \times 24} = \frac{324\,000}{2592} = 125 \text{ lbs.}$$

Flues, Arched or Circular Furnaces. *U. S. La[illegible]*

.3125 inch for each 16 ins. of diameter. English iron, being harder [illegible] American, is better constructed to resist compression, and consequently less thickness of metal is required for like stress.

Lloyd's.

$\frac{89\,600\,t^2}{L\,D} = P$, $\sqrt{\frac{P\,L\,D}{89\,600}} = t$, $\frac{89\,600\,t^2}{P\,L} = D$, and $\frac{89\,600\,t^2}{P\,D} = L$. *D representing external diameter of flue or furnace, and t thickness of plate, both in ins., L length of flue or furnace between its ends or between its rings, in feet, and P working pressure in lbs. per sq. inch.*

Illustration.—Assume diameter of flue 16 ins., length 6 feet, and working pressure [illegible] lbs. per sq. inch.

Then $\sqrt{\frac{[illegible] \times 6 \times 16}{89\,600}} = \sqrt{[illegible]} = [illegible]$ inch. Furnaces.—P [illegible]

'ties of Current of Heated Air in a Chimney 100 *Feet in Height.*

In Feet per Second.

ir.	Air at Base of Chimney. 150°	250°	350°	450°	External Air.	Air at Base of Chimney. 150°	250°	350°	450°
	Feet.	Feet.	Feet.	Feet.		Feet.	Feet.	Feet.	Feet.
	24	30	33	35	60°	19	26	29	33
	22	28	31	34	70°	18	25	29	32
	20	27	30	33	80°	17	24	28	32

Height of Chimney is less than 100 *feet.*—Multiply velocity as ob-
r temperature by .1 square root of height of chimney in feet.

ıt consequent upon a steam-jet in a smoke-pipe or chimney is
ual to that of a moderate blast.

ost effective draught is when absolute temperature of heated air or
that of external air as 25 to 12, or nearly equal to temperature of
ead.

nneys of gas retorts, ovens, and like furnaces, the draught is more
or a like height of chimney than in ordinary furnaces, in con-
of the great mass of brick masonry, which, becoming heated, adds
ity of draught.

:hirmneys. *Lawrence Manufacturing Co., Mass. Octagonal.*
above ground 211 feet. Diameters 15, and 10 feet 1.5 ins. Wall at base
at top 11.5 ins. Shell at base 15 ins., at top 3.75 ins.
tion 22 feet deep.

d.—Square.—Height........190 feet. Diameter at base........20 feet.
" " ....300 " " " ....29 "
Round. " ....312 " " " ....30 "
" " ....300 " " " ....20 "

er at base usually 1 of height above ground.

m at base of chimney ranges from .375 to .43 ins. of water.

Circulating Pumps.

-acting. — .6 volume of single-acting air-pump and .32 of double-

:-acting. — .53 volume of double-acting air-pump.

Volume of Pump compared to Steam Cylinder or Cylinders.

:ngine.	Pump.	Volume.
pansive, 1.5 to 5 times........	Single-acting	.08 to .045.
mpound......................	do.	.045 to .035.
pansive, 1.5 to 5 times........	Double-acting.........	.045 to .025.
mpound......................	do	.025 to .02.

s.—Area such as to restrict the mean velocity of the flow to 450 feet
ıte.

PLATES AND BOLTS.

ıught-iron.—Tensile strength ranges from 45 500 to 70 000 lbs.
nch for plates, and 60 000 to 65 000 lbs. for bolts, being increased
bjected to a moderate temperature.
sh plates range from 45 000 to 56 000 lbs., and 55 000 to
bs.
:lark gives best quality of Yorkshire 56 000 lbs., of

of Plates. *(U. S.)*—All plates to be stamp
ır ins. from edge, and also in or near to their cent.
his location, and tensile stress they will bear.
ubjected to a tensile stress under 45 000 lbs. per sq.
section 12 *per cent.*, 45 000 and under 50 000, 15, al
rupture.

ILLUSTRATION.—Assume $T = 50\,000$ *lbs.* tensile strength of plate, $B = .75$ per ..., $D = 120$ *ins.*, $C = 5$, and $t = .5$. What pressure will shell sustain, and what sh... be thickness of plates for such pressure and diameter?

$$\frac{50\,000 \times .75 \times .5 \times 2}{120 \times 5} = 62.5 \text{ lbs., and } \frac{120 \times 62.5 \times 5}{50\,000 \times .75 \times 2} = .5 \text{ inch.}$$

For all practicable deficiencies in drilling, punching, and riveting in tra... verse courses, if existing, this coefficient is increased up to 6.75, and in lo... gitudinal courses to 8.75, and when courses are not properly broken, a... addition is made to above of .4.

Diameter of rivets should not be less than thickness of plates.

Molesworth.

$\frac{P\,d}{2\,t} = C$, $\frac{2\,t\,C}{d} = P$, and $\frac{P\,d}{2\,C} = t$. *d representing diameter and t thickness of metal, both in ins., P working pressure in lbs. per sq. inch, and C as follows:*

		Single riveted.	Double ...
Best Yorkshire plates......	one ninth of tensile strength.	$C = 6200$	and 7...
" Staffordshire plates....		" $= 5000$	" 6...
Ordinary plates............		" $= 3000$	" 37...

Working stress not to exceed .2 tensile strength of joint or riveted pla...

Then for a pressure of 110 lbs., and a diameter of 42 ins., as given for a s... U. S. boiler.

Taking C as above for best single-riveted plate at 6200, $\frac{110 \times 42}{2 \times 6200} = .372$... *in thickness, or .122 inch in excess of U. S. Law for a plain cylindrical boiler, ... riveted.*

Lloyd's.

Thickness of shells to be computed from strength of longitudinal joi...

$\frac{t\,J\,C}{D} = P$, $\frac{P\,D}{C\,J} = t$, $\frac{t\,J\,C}{P} = D$, $\frac{p - d}{p} = x$, and $\frac{n\,a}{p\,t} = z$. *t representing thick-ness of plate, D diameter of shell, p pitch and d diameter of rivets, all in ins.; J per cent. of strength of joint or rivets, the least to be taken; C a constant as per ta... P working pressure in lbs. per sq. inch; n number and a area of rivet; x per ... of strength of plate at joint compared with solid plate, and z per cent. of streng... rivets compared with solid plate.*

When plates are drilled, take .9 of z, and when rivets are in double sh... put 1.75 a for a.

Constants.

JOINT.	IRON PLATES. .5 inch and under.	.75 inch and under.	Above .75 inch.	STEEL PLATES. .375 inch and under.	.5625 inch and under.	.75 inch and under.
Lap, punched holes........	155	165	170	200	215	230
Lap, drilled do.	170	180	190	—	—	—
Double abut strap, punched holes	170	180	190	215	230	250
Double abut strap, drilled do.	180	190	200	—	—	—

When plates, as in steam-chimneys, superheaters, etc., are exposed to d... tion of the flame, these constants are to be reduced .33.

ILLUSTRATIONS. — Assume pitch 4 ins., diam. of rivet 1.375 ins., and thickness of plate 1 inch, both single and double riveted. Area $1.375 = 1.48$ *sq. ins.*

$\frac{4 - 1.375}{4} = .656$ *per cent. strength of joint compared to solid plate.* $\frac{1 \times 1.48}{4 \times 1} = ...$ *per cent. strength of rivet to solid plate when single riveted*, and $\frac{1.75 \times 1.48}{4 \times 1} = ...$ *per cent. when double riveted.* Rivets at Joint. $\frac{n\,a}{p\,t} \times 100$ *with punched ho... by 90 with drilled.*

Plates.

npute Thickness of Plates for a Given Pressure 'itch, and Pressure and Pitch for Given Thick-

, $\sqrt{\frac{t^2\,C}{P}} = p$, and $\sqrt{\frac{P\,p^2}{C}} = t$. *t representing thickness of metal in of an inch, p pitch of stays or distance apart at centres in ins.*, P *working ı lbs. per sq. inch, and* C *a constant, as follows:*

'or a Tensile Strength of Metal of 50 000 *Lbs. per Sq. Inch.*

'ay-bolts with Riveted Heads.—Plates up to .4375 *inch in thickness* C = 90, *that* 100.

tay-bolts with Nuts.—Plates up to .4375 *inch in thickness* C = 110, *and* 120.

tay-bolts with Double Nuts and Washers.—Up to 4.375 *ins. in thickness ıd above that* 160.

ay-bolts are not exposed to corrosion, these constants may be reduced .2.

nce of a flat surface decreases in a higher ratio than space between [ence, C must be decreased in proportion to increase of pitch above dinary boiler-plates.

ATION 1.—Assume pressure 110 lbs. per sq. inch, and pitch of stays 5 ins.; ld be thickness of plate for screw-bolts and riveted heads?

$$C = 95. \quad \text{Then } \sqrt{\frac{110 \times 5^2}{95}} = \sqrt{\frac{2750}{95}} = 5.38\text{— } \textit{sixteenth.}$$

ume thickness of metal 5 sixteenths inch thick, stay-bolts screwed and er its threads, and working pressure of steam 80 lbs. per sq. inch.

$$C = 95. \quad \text{Then } \sqrt{\frac{5^2 \times 95}{80}} = 5.45 \textit{ ins. pitch.}$$

Abut Straps.

Abuts should be at least .625 thickness of plate covered. *Single,* xer than plate covered, and *Double*, .625.

Stays.

—Tensile stress should not exceed 5000 lbs. per sq. inch for Iron, for Steel.

ıal or Oblique.—Ascertain area of direct stay required to sustain ce; multiply it by length of diagonal stay, and divide product by a line drawn at a right angle to surface stayed, to end of diagonal quotient will give area of stay increased to that which is required.

upon an oblique stay is also equal to stre... perpendicular porting a like surface would sustain, di... angle forms with perpendicular to surface to b...

:ATION.—Assume pressure 110 lbs. per sq. inc , and angle of stay 45°; what would be pressu

Cosine 45° = .707 11. Then 110 × 36 ÷ .707

Efficiency of boiler. $1.833\left(\frac{1600}{1600\times 2+800}\right)=.733.$

The evaporative power of different fuels, from and at 212°. lb. for coals [illegible] to 16.8 lbs., the average of Newcastle being 15.3, for patent fuels 15.6[illegible], L[illegible] Coke 13.3, Peat 10.3, and Woods, when dry, 8.1. *See A. E. Seaton. London* [illegible]

Notes on Horse-power.

A Lancashire boiler with a heating surface of 610 sq. feet and a grate-a[illegible] will evaporate in ordinary operation 50 cube feet of water per hour; 3.12 sq. [illegible] horizontal section per cube foot of water, and .5 sq. foot of grate-area per cu[illegible]

Nominal. *Flue Boilers.*—Usually computed at 5.5 to 6 sq. feet of hor[illegible] section, 15 sq. feet of heating surface, and 1 sq. foot of grate-area.

The IHP of such boilers will range from 3 to 4 times that of the nominal.

Multitubular Boilers.—.75 sq. foot of grate-area and 2.5 of heating surface.

Weights of Steam-engines.

Side-wheels.—*American Marine (Condensing).*

Engine.	Frame.	Water-wheels.	Cylinders. No.	Cylinders. Volume.	Weight per Cube Foot.	Ser[illegible]
				Cube Feet.	Lbs.	
Vertical beam...........	Wood.*	Wood.	1	63	1100	Er[illegible]
"	Wood.*	Wood.	2	216	1040†	Co[illegible]
"	Wood.*	Wood.	1	430	1225	Co[illegible]
"	Wood.*	Wood.	2	253	1480‡	Co[illegible]
"	Wood.*	Iron.	1	725	1089†	Se[illegible]
Oscillating..............	Iron.	Iron.	2	540	850	Se[illegible]
"	Iron.	Iron.	2	1502	550§	Se[illegible]
Inclined.................	Iron.	Iron.	2	535	1100	Se[illegible]

* Without frame. † With frame 1109. ‡ Including boilers. § Single [illegible]

Screw Propellers.—*American Marine (Condensing).*

Engine.	Cylinders. No.	Cylinders. Volume.	Weights. Engine.	Weights. Boilers.	Weights. Per C. Ft. Cylinder.
		Cube Feet.	Lbs.	Lbs.	Lbs.
Vertical direct, Jet Condens'g..	1	4	22 040	12 100	8535
" " Surface Cond'g.	1	12.5	59 000	32 000	7280
" " Jet " .	1	12.5	48 130	35 000	6650
" " " " .	1	33	120 450	98 000	6620
" " " " .	4	506	1 523 060	985 600	4958
Horizontal back-action........	2	68	289 680	200 800	7212
" direct.............	2	67	201 000	200 593	6009
Vertical compound...... (Surface Condens'g)	2	4.8	24 705	26 372	10641
" " ...... (Surface Condens'g)	2	24.3	94 196	88 050	7500
" " ...... (Surface Condens'g)	2	425	1 022 400	840 000	4380
" direct.......... (Surface Condens'g)	1	3.6	30 534	27 301	10066
" " .... (Surface Condens'g)	1	35	172 028	100 065	7774
" " Non-Condensing.	1	1.86	14 410	22 481	19834
" " " "	1	2.77	14 759	22 417	13421

English Marine (Condensing).

Description.	Cylinders. No.	Cylinders. Volume.	Weights. Engines.	Weights. Propeller and Shafting.	Weights. Boilers and Water.	Weights. Total.	Per IHP
		Cube Ft.	Tons.	Tons.	Tons.	Tons.	Lbs.
Trunk	2	230	121	47	257	425	465
Horizontal	2	382	223	85	303	611	338
..	2	393	165	48	144	357	781
.	2	440	117	43	135	295	560
.	2	24	4.25	.75	7.25	12.25	60
	6	707	497	167	656	1320	358
	[illegible]	52	55	15	110	180	35[illegible]
	[illegible]	143	130	87	162	319	[illegible]

Land-engines.—(*Non-condensing.*)

ENGINE.	Volume of Cyl'r.	Engine.	Spur-wheel and Connections.	Sugar-Mill Complete.	Boilers, Grates, etc.	Engine per Cube Foot of Cylinder.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
I} 18 ins. × 4 feet	7	67 200	37 800	89 600	26 880	9600
I} 30 ins. × 5 feet	24.5	105 000	137 179	265 879	75 000	4290
a'l, 14 ins. × 2 feet	2.2	10 914	—	—	8 200	5100
22 ins. × 4 feet	10.6	56 000	—	—	30 140	5600

ompute Weight of a Vertical Beam and Side-wheel Jet Condensing Engine. (*T. F. Rowland, A.S.C.E.*)

ing all Metals, Boiler and Attachments, Smoke-pipe, Grates, Iron Floors, and Iron in Wooden Water-wheels, omitting Coal-bunkers.

For a Pressure per Mercurial Gauge of 40 *lbs. per Sq. Inch.*

For surface condenser add 10 *to* 15 *per cent.*

E.—Multiply volume of cylinder in cube feet by *Coefficient* in follow- ɔle corresponding to length of stroke, and product will give rough in lbs. For finished weight deduct 6 per cent.

.	Coefficient.	Stroke.	Coefficient.	Stroke.	Coefficient.	Stroke.	Coefficient.
		Feet.		Feet.		Feet.	
	2467	7	2213	9	1865	11	1619
	2340	8	2000	10	1730	12	1546

PLE 1.—What are the rough and finished weights of a vertical beam engine, r 80 ins. in diameter and 12 feet stroke of piston?

of 80 ins. = 5026.56, which × 12 *feet* = 419 *cube feet*, and × 1546 for 12 feet = 647 774 *lbs. rough weight.*

647 774 × .06 = 38 866, and 647 774 − 38 866 = 608 908 *lbs. finished weight.*

WEIGHTS OF BOILERS.

:s of Iron Boilers (including Doors and Plates, and exclusive of Smoke-pipes and Grates) per Sq. Foot of Heating Surface.

ace Measured from Grates to Base of Smoke-pipe or Top of Steam Chimney.

BOILER. *For a Working Pressure of* 40 *Lbs.*	Weight.
	Lbs.
return, Flue*..............................water bottom....	25.6 to 32.9
" " .... —	24 to 30
" " Multi-flue*..................water bottom....	27 to 45
" " " .... —	25 to 43
ɔtal return, Tubular†......................water bottom....	22.5 to 35
" " †...................... —	21 to 33
" " *...................... —	17.7 to 26.7
l " " †......................water bottom....	18.5 to 26.5
ɔtal direct, Tubular*...................... " "	19.8 to 23.8
" " *...................... —	17 to 21
·ical, external furnace,‡ 36 ins. in diam., .25 inch thick.......	23.5 to 24
Flue " ‡ 36 to 42 " .25 " "	18.1 to 18.6
ntal direct, Tubular........................Locomotive......	16.3 to 17.3
.l Cylinder direct, Tubular.................. —	24 to 26

ht of Cylindrical Furnace and Shell Boilers, all complete for Sea Service and ressure of 60 lbs. steam, 200 lbs. per IHP.

ion of furnace square. Shell cylindrical. † Section of furnace and shell square. ught-iron heads, .375 inch thick, flues, .25 inch, and surface computed to half diameter of shell.

:s.—1. The range in the units of weight arises from peculiarities of construc- ɔnsequent upon proportionate number of flues ... ·shell compared with heating surface, ...

pressure is increased the above units ...

Boiler-power.

The power of a boiler is the volume or weight of steam alone (indepen-dent of any water that it may hold in suspension) that it will generate at its operating pressure in a unit of time.

Marine boilers of the ordinary type and proportions, with natural draught, burn-ing anthracite coal, produce 3.5 to 5.5 IHP per sq. foot of grate per hour; with free burning or a semi-bituminous coal, 5 to 7.5 IHP; and with a forced draught with 25 to 30 lbs. best coal per sq. foot of grate per hour, 8 to 10 IHP.

Marine engines, operating with a steam-pressure of 35 lbs. (m. g.), and with mod-erate expansion, consume 30 lbs. steam per IHP per hour, and with a high rate of expansion, under a pressure of 70 lbs., 20 lbs. steam.

With a blast draught and consuming 30 to 40 lbs. of a fair quality of coal per sq. foot of grate per hour, 7 to 10 IP per hour can be attained.

In locomotive boilers, having from 50 to 90 sq. feet of heating surface per sq. foot of grate, and at a rate of combustion of from 45 to 125 lbs. of coke, an average evap-oration of 9 lbs. of water per lb. of coke has been attained at ordinary temperature and pressure.

To Compute Volume of Air and Gas in a Furnace.

When Volume at a Given Temperature is known. RULE.—Multiply given volume by its absolute temperature, and divide product by the given abso-lute temperature.

NOTE.—Absolute temperature is obtained by adding 461° to given or assumed temperature.

EXAMPLE.—Assume volume of air entering a furnace at 1 cube foot, its tempera-ture 60°, and temperature of furnace 1623°; what would be the increase of volume?

$$\frac{1 \times \overline{1623^\circ + 461^\circ}}{60^\circ + 461^\circ} = \frac{2084}{521} = 4 \textit{ times.}$$

Volume of Furnace Gas per Lb. of Coal. (Rankine.)

Tempera-ture.	Air Supplied. 12 Lbs.	18 Lbs.	24 Lbs.	Tempera-ture.	Air Supplied. 12 Lbs.	18 Lbs.	24 Lbs.
32°	150	225	300	752°	369	553	[illegible]
68	161	241	322	1112	479	718	[illegible]
104	172	258	344	1472	588	882	[illegible]
212	205	307	409	1832	697	1046	[illegible]
572	314	471	628	2500	906	1357	[illegible]

Temperature of ordinary boiler furnaces ranges from 1500° to 2500°.

The opening of a furnace door to clean the fire involves a loss of from 4 to 1[illegible] per cent. of fuel.

For other illustrations, see *ante*, page 744–6.

Rate of Combustion.

The rate of combustion in a furnace is computed by the lbs. of fuel consumed per sq. foot of grate per hour.

In general practice the rate for a natural draught is, for anthracite coal from [illegible] 16 lbs., for bituminous, from 10 to 25 lbs., and with artificial or forced draught, as a blower, exhaust-blast, or steam-jet, the rate may be increased from 30 to [illegible]

The dimensions or size of coal must be reduced and the depth of the fire [illegible] directly, as the intensity of the draught is increased.

Temperature of gases at base of chimney or pipe should be 600°, and resistance of surface of chimney is as square of velocity of current of gas.

Ordinarily from 20 to 32 per cent. of total heat of combustion is exp[illegible] production of the chimney draught in a marine boiler, to which is to [illegible] losses by incomplete combustion of the gaseous portion of the fuel [illegible] of the gases by an excess of air, making a total of fully 60 per cent. *Wm. H. Shock, U. S. N.*, 1881.)

STRENGTH OF MATERIALS.

ıgth of a material is measured by its resistance to alteration of vhen subjected to stress and to rupture, which is designated as ng, Detrusive, Tensile, Torsion, and Transverse, although trans- s a combination of tensile and crushing, and detrusive is a form ion at short lengths of application.

ELASTICITY AND STRENGTH.

ngth of a material is resistance which a body opposes to a per- t separation of its parts, and is measured by its resistance to ion of form, or to stress.

ion is force with which component parts of a rigid body adhere to her.

icity is resistance which a body opposes to a change of form.

icity and *Strength*, according to manner in which a force is exerted body, are distinguished as *Crushing Strength*, or Resistance to Com- 1; *Detrusive Strength*, or Resistance to Shearing; *Tensile Strength*, olute Resistance; *Torsional Strength*, or Resistance to Torsion; and *erse Strength*, or Resistance to Flexure.

t of Stiffness is flexure, and limit of Resistance is fracture.

ral Axis, or *Line of Equilibrium*, is the line at which extension ter- s and compression begins.

ience, or toughness of bodies, is strength and flexibility combined; any material or body which bears greatest load, and bends most at fracture, is toughest.

st bar or beam that can be cut out of a cylinder is that of which s to breadth as square root of 3 to 1; *strongest*, as square root of 2 to most *resilient*, that which has breadth and depth equal.

s expresses condition of a material when it is loaded, or extended in of its elastic limit.

ral law regarding deflection is, that it increases, *cæteris paribus*, di- as cube of length of beam, bar, etc., and inversely as breadth and cube h.

tance of *Flexure* of a body at its cross-section is very nearly .9 of its resistance.

Coefficient of Elasticity.

icity of any material subjected to a tensile or compressive force, its limits, is measured by a fraction of the length, per unit of force t of sectional area, termed a *constant*, and coefficient of elasticity is defined as the weight which would stretch a perfectly elastic bar of 1 section to double its length.

of force and area is usually taken at one lb. per sq. inch. E *represent- ominator of fraction.*

PLE.—If a bar of iron is extended one 12 000 000th part of its length per lb. s per sq. inch of section, $\frac{1}{12\,000\,000} = \frac{1}{E}$.

ar would, therefore, be stretched t~ by a force of o lbs per sq. inch, if the material

The same method of expressing coefficient of elasticity is applied to resistance to compression. That is, coefficient, in weight, is expressed by denominator of fraction of its length by which a bar is compressed per unit of weight per sq. inch of section.

Ultimate extension of cast iron is 500th part of its length.

Extension of Cast-iron Bars, when suspended Vertically.

1 Inch Square and 10 Feet in Length. Weight applied at one End.

Weight.	Extension.	Set.	Weight.	Extension.	Set.	Weight.	Extension.	Set.
Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.
529	.0044	—	2117	.0190	.000059	8468	.0871	.00[illegible]
1058	.0092	.000015	4234	.0397	.00265	14820	.1829	.00[illegible]

Woods.—MM. Chevaudier and Wertheim deduced that there was no limit of elasticity in woods, there being a permanent set for every extension. They, however, adopted a set of .00005 of length as limit of elasticity. This is empirical.

MODULUS OF ELASTICITY.

Modulus or *Coefficient of Elasticity* of any material is measure of its elastic reaction or force, and is height of a column of the material pressing on its base, which is to the weight causing a certain degree of compression as length of material is to the diminution of its length.

It is computed by this analogy: As extension or diminution of length of any given material is to its length in inches, so is the force that produced that extension or diminution to the modulus of its elasticity.

Or, $x : \mathrm{P} :: l : w = \frac{\mathrm{P}\,l}{x}$. *x representing length a substance 1 inch square and 1 in length would be extended or diminished by force* P, *and w weight of modulus in*

To Compute Weight of Modulus of Elasticity.

RULE.—As extension or compression of length of any material 1 inch square, is to its length, so is the weight that produced that extension or compression, to modulus of elasticity in lbs.

EXAMPLE.—If a bar of cast iron, 1 inch square and 10 feet in length, is extended .008 inch, with a weight of 1000 lbs., what is the weight of its modulus of elasticity?

$.008 : 120\ (10 \times 12) :: 1000 : 15\,000\,000$ *lbs.*

To Compute Modulus of Elasticity.

When a Bar or Beam is Supported at Both Ends and Loaded in Centre.

RULE.—Multiply weight or stress per sq. inch in lbs. by length of material in ins., and divide product by modulus of weight.

Or, $\frac{l\,\mathrm{W}}{\mathrm{M}} = \mathrm{E}$; $\frac{l\,\mathrm{W}}{\mathrm{E}} = \mathrm{M}$; $\frac{\mathrm{E\,M}}{l} = \mathrm{W}$. *l representing length in ins.*, M *modulus*, W *weight in lbs. per sq. inch, and* E *compression or extension.*

EXAMPLE 1.—If a wrought-iron rod, 60 feet in length and .2 inch in diameter, is subjected to a stress of 150 lbs., what will it be extended?

[illegible] of elasticity of iron wire is 28 230 500 *lbs.* (see following table), and [illegible] $= .314\,16$.

$= 477.46$ *lbs. per sq. inch*, and $60 \times 12 = 720$ *ins.*

$= \frac{343\,771.2}{28\,230\,500} = .012\,18$ *inch.*

[illegible]e under rule for weight of modulus.

$\frac{.008 \times 15\,000\,000}{120} = 1000$ *lbs.*

›dulus of Elasticity and Weight of Various Materials.

Substances.	Height.	Weight.	Substances.	Height.	Weight.
	Feet.	Lbs.		Feet.	Lbs.
....	4 970 000	1 656 570	Larch............	4 415 000	1 074 000
ɔh............	4 600 000	1 345 000	Lead, cast.........	146 000	720 000
ss, yellow.....	2 460 000	8 464 000	Lignum-vitæ.....	1 850 000	1 080 400
wire.......	4 112 000	14 632 720	Limestone........	2 400 000	3 300 000
per, cast......	4 800 000	18 240 000	Mahogany.........	6 570 000	2 071 000
....	5 680 000	1 499 500	Marble, white.....	2 150 000	2 508 000
red	8 330 000	2 016 000	Oak..............	4 750 000	1 710 000
ss............	4 440 000	5 550 000	Pine, pitch	8 700 000	2 430 000
-metal........	2 790 000	8 844 300	" white	8 970 000	1 830 000
ɔpen fibres....	5 000 000	170 000	Steel, cast	8 530 000	26 650 000
....	6 000 000	2 370 000	" wire........	9 000 000	28 689 000
ı, cast.........	5 750 000	17 968 500	Stone, Portland ...	1 672 000	1 718 800
wrought.....	7 550 000	25 820 000	Tin, cast..........	1 053 000	3 510 000
wire	8 377 000	28 230 500	Zinc..............	4 480 000	13 440 000

Veight a Material will bear per Sq. Inch, without Permanent Alteration of its Length.

Material.	Lbs.	Material.	Lbs.	Material.	Lbs.
Metals.		*Stones, etc.*		*Woods.*	
ss...........	6 700	Marble	4900	Beech...........	2360
ı metal......	10 000	Limestone*.....	2000	Elm.............	3240
ɔ, cast.......	15 000	Portland........	1500	Fir, red..........	4290
wrought...	17 800			Larch	2060
d...........	1 500	*Woods.*		Mahogany......	3000
ɔl	45 000	Ash	3540	Oak.............	3960

* Tensile strength 2800.

Comparative Resilience of Woods.

.... 1	Chestnut...... .73	Larch.......... .84	Spruce......... .64
ɔh........ .86	Elm........... .54	Oak........... .63	Teak........... .59
ɾ........ .66	Fir............ .4	Pitch Pine..... .57	Yellow Pine... .64

MODULUS OF COHESION.

Compute Length of a Prism of a Material which would be Severed by its own Weight when Suspended.

ɔLE.—Divide tensile resistance of material per sq. inch by weight of a of it in length, and quotient will give length in feet.

·USTRATION.—Assume tensile resistance of a wrought-iron rod to be 60 000 lbs. q. inch. Weight of 1 foot = 3.4 *lbs.*

Then $60\,000 \div 3.4 = 17\,647.06$ *feet.*

Length in Feet required to Tear Asunder the following Substances:

ɔ ide...... 15 375 feet. | Hemp twine... 75 000 feet. | Catgut........ 25 000 feet.

ɔsticity of Ivory as compared with Glass is as .95 to 1.

ɔhen Height is given. RULE.—Multiply weight of 1 foot in length and ɔh square of material by height of its modulus in feet, and product will weight.

To Compute Height of Modulus of Elasticity.

ɔLE.—Divide weight of modulus of elasticity of mate- weight of ɔt of it, and quotient will give height in feet.

ɔAMPLE.—Take elements of preceding case (page 762), w - ; what is height of its modulus of elasticity?

$15\,000\,000 \div 3 = 5\,000\,000$ *feet.*

Crushing Strength of any body is in proportion to
and inversely as its height.

In tapered columns, it is determined by the least d

When height of a column is not 5 times its side or
strength is at its maximum.

Cast Iron.—Experiments upon bars give a mean cr
100 000 lbs. per sq. inch of section, and 5000 lbs. per sq. in
to overcome elasticity of metal; and when height exceed
the iron yields by flexure. When it is 10 times, it is re
when it is 15 times, as 1 to 2; when it is 20 times, as 1
times, as 1 to 4; and when it is 40 times, as 1 to 6.

Experiments of Mr. Hodgkinson have determined tl
strength of about one eighth of destructive weight is obt
diameter of a column in its middle.

In columns of same thickness, strength is inversely
$^{1.63}$ power of length nearly.

A hollow column, having a greater diameter at one e
has not any additional strength over that of an uniform

Wrought Iron.—Experiments give a mean crushing st
per sq. inch, and it will yield to any extent with 27 00
while cast iron will bear 80 000 lbs. to produce same effect

Effects.—A wrought bar will bear a compression of $\frac{1}{881}$
out its utility being destroyed.

With cast iron, a pressure beyond 27 000 lbs. per sq.

...hing Strength of various Materials, deduced from ...periments of Maj. Wade, Hodgkinson, Capt. Meigs, ...S. A., Stevens Institute, and by G. L. Vose.

Reduced to a Uniform Measure of One Sq. Inch.

Cast Iron.

...ures and Material.	Crushing Weight.	Figures and Material.	Crushing Weight.
	Lbs.		Lbs.
...tal, American.........	174 803	Clyde, average, English........	82 000
"	85 000	Stirling, mean of all, English ..	122 395
	125 000	" extreme, English.....	134 400
mean.............	100 000	Extreme, English...........	53 760
...or, No. 1, English......	62 450		153 200
No. 2, "	92 330	Average (Hodgkinson), English	84 240
No. 3, "	106 039	Blaenavon No. 2..............	109 700

Wrought Iron.

...an, extreme..........	127 720	English.....................	65 200
	83 500		40 000
mean.............	47 040	" average..............	37 850

Various Metals.

...ium bronze, 95 cop.....	129 920	Steel, Bessemer...............	50 000
...ass....................	164 800	" " soft...........	66 200
...pper...................	117 000	" tempered...............	335 000
...ast..................	105 000	" Siemens................	
	250 000	Tin, cast......................	15 500
...agersta	154 500	Lead..........................	7 730

...tic Crushing Strength of Wrought Iron and Crucible Steel is equal to its ten... Bessemer Steel, 50 per cent. of its transverse strength.

Woods.

....	6 663	Maple......................	8 100
....	6 963		10 000
....	3 300	Oak, American white..........	7 500
	7 900	" Canadian white..........	5 982
....	10 513	" " live..........	6 850
...red..................	5 968	" English...............	9 500
...seasoned...............	6 500		6 484
...ut....................	5 350	" Dantzic, dry.............	7 700
....	6 831	Pine, pitch..................	8 947
...soned.................	10 000	" white..................	5 775
...glish....	10 300	" yellow.................	8 200
...y, white..............	8 925	" Deal, Christiana.........	5 850
....	3 200	Spruce, white.................	5 950
	5 500	Teak..........................	12 100
....	9 113	Walnut.......................	6 645
...ny, Spanish...........	8 198	Willow, seasoned..............	6 000

Crosswise of Fibre.

.... 2300 | Larch.............. 1300 | Pines.............. 550

...se in Strength of Cubes of Sandstone, per Sq. Inch (under Blocks ...Wood), as Area of Surface is increased. (*Gen'l Gillmore, U. S. A.*)

Stone.	Inches. .5	1	1.5	2	2.25	2.75	3	4
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Berea sandstone ..	6080	6990.	8 226	8 955	9 130	9 838	10 125	11 720
" " ..	—	9500	10 730	12 000	12 500	13 100	—	—

Stones, Cements, etc. *(Per Sq. Inch.)*

Figures and Material.	Crushing Weight.	Figures and Material.
	Lbs.	
Basalt, Scotch	8 300	Granite, Patapsco, Md.
" Welsh	16 800	" Portland, Eng.
Beton, N. Y. S. Concreting Co.	800 1 400	" Quincy, Mass.
Brick, pressed	6 222 10 219	Greenstone, Irish Limestone
" Gloucester, Mass.	14 216*	
" hard burned	3 630	" compact, Eng.
" common	800 4 000	" Magnesian, " " Anglesea "
" yellow-faced burned, Eng.	1 440	" Irish "
" Stourbridge fire-clay, "	1 650	Marble, Baltimore, Md.
" Staffordshire blue, "	7 200	
" stock, English	2 250	" East Chester, N. Y.†
" Fareham, English	5 600	" Hastings, N. Y.
" red, English	808	" Irish
" Sydney, N. S.	2 228	" Italian
Caen, France	1 543	" " white
Cement, Hydraulic, pure, Eng.	17 000 32 000	" Lee, Mass. " Montgomery Co., Pa
" Portland, sand 1	1 280	" Statuary
" " sand 3	600	" Stockbridge, Mass.‡
" " 3 mos.	3 800	" Symington, large
" " 1 sand, 3 mos.	2 464	" " fine crystal
" " 9 mos.	5 980	" " strata horizo
" " 1 sand, 9 mos.	2 330	Masonry, brick, common
" " 12 inch cubes, 12 mos. 1 sand and gravel	2 650	" " in cement Mortar, good
" " 3 " "	1 800	" lime and sand
" Roman	342	" " " beaten
" " pure, Eng.	750	" common
" Rosendale	3 270	Oolite, Portland
" Sheppey, Eng.	1 280	Pottery-pipe, Chelsea
Concrete, lime 1, gravel 3	460 775	Sandstone, Aquia Creek § " Arbroath, Eng.
Freestone, Belleville, N. J.	3 522	" Connecticut
" Connecticut	3 319	" Craigleth, Eng.
" Dorchester, Mass.	3 069	" Derby grit "
" Little Falls, N. Y.	2 991	" Holyh'd quartz, E
Glass, crown	31 000	" Seneca ‖
Gneiss	19 600	" Yorkshire, Eng.
Granite, Aberdeen, Eng.	10 760	Slate, Irish
" Cornish, "	6 339	
" Dublin, "	10 450	Terra Cotta
" Newry, "	12 850	Whinstone, Scotch

* Tested by author at Stevens' Institute, N. J. † Post-office, Wash. ‡ City Hall, § Capitol, Treasury Department, and Patent Office, Washington, D. C. ‖ Smithsonia

Safe Load of Hollow, Cylindrical, and Solid Co Arches, Chords, etc., of Cast Iron.

Hollow Columns. Per Sq. Inch. (F. W. Shields, M. I. C. E.)

Length.	Thickness.	Load.	Length.	Thickness.	Load.	Length.	Thickness.	Load.	Length.
	Inch.	Lbs.		Inch.	Lbs.		Inch.	Lbs.	
	375	2800	20 to 24	.625	3920	25 to 30	.375	2240	25 to 30
		3360	diam's.	.75	4480	diam's.	.5	2800	diam's.

Columns, etc.—3360 lbs. per sq. inch. (Brunel.)

4600 lbs. per sq. inch.

[...]nd Posts.—1 inch diameter and not more than 15 diameters in [...]aking weight of metal.

[...]neter and not more than 25 diameters in length .5 of breaking weight [...]when more than 25 diameters in length from .1 to .025 of breaking [...]l. (*Baltimore Bridge Co.*)

[...]t-iron Cylinders and Rectangular Tubes.

	External Diameter.		Internal Diameter.	Thickness.	Area.	Crushing Weight per Sq. Inch.
[...]s.	Ins.		Ins.	Ins.	Sq. Ins.	Lbs.
	1.495		1.292	.1	.444	14 661
	2.49		2.275	.107	.804	29 779
	6.366		6.106	.13	2.547	35 886
[T]UBES.						
	4.1	×	4.1	.03	.504	10 980
	4.1	×	4.1	.03	.504	11 514
	4.1	×	4.1	.06	1.02	19 261
	4.25	×	4.25	.134	2.395	21 585
	4.25	×	4.25	.134	2.395	23 202
	8.4	×	4.25	{ .26 / .126	6.89	29 981
	8.1	×	8.1	.06	2.07	13 276
	8.1	×	8.1	.06	2.07	13 300
[...]ternal	8.1	×	8.1	.0637	3.551	19 732
[...]phrag's	8.1	×	8.1	.0637	3.551	23 208

[...]per Sq. Inch of 2-Inch Cubes under Blocks of Wood. (*Gen'l Gillmore, U. S. A.*)

Surfaces Worked to a Clear Bed.

	Lbs.
blue	22 250
	15 000
	17 750
	14 750
Co., N. Y	18 250
[...]nt, Conn.	16 187
Conn.	12 500
[...]a.	21 250
" gray	14 100
[...]ss.	{ 12 423 / 19 500
[...]I., gray	14 937
[M]ass., gray	15 937
[...]dson River, gray	13 370
[...]., dark	17 750
, bluish gray	12 875
[...]al Park, N. Y., red	17 500
N. J., soap	20 750
" gray	24 040
N. Y	11 475
[...]lain, N. Y.	25 000
N. Y	20 700
"	13 900
"	18 500
O., white	12 600
[...]hite	16 900
Mich., drab	{ 18 000 / 25 000
[...], *Wis., bluish drab*	21 500

	Lbs.
LIMESTONE.	
Bardstown, Ky., dark	16 250
Cooper Co., Mo., dark drab	6 650
Erie Co., N. Y., blue	12 250
Caen, France	3 650
MARBLE.	
East Chester, N. Y.	13 504
Italian, common	13 062
Dorset, Vt.	7 612
Mill Creek, Ill., drab	9 687
North Bay, Wis., drab	20 025
SANDSTONE.	
Little Falls, N. Y., brown	9 850
Belleville, N. J., gray	11 700
Middletown, Conn., brown	6 950
Haverstraw, N. Y., red	4 350
Medina, N. Y., pink	17 725
Berea, O., drab	{ 7 250 / 10 250
Vermillion, O., drab	8 850
Fond du Lac, Wis., purple	6 250
Marquette, Mich., "	[...]50
Seneca, O., red brown	
Cleveland, O., olive green	
Albion, N. Y., brown	
Kasota, Minn., pink	
Fontenac, Minn., light bu[ff]	
Craigleth, Edinburgh	
Dorchester, N. B., freeston[e]	
Massillon, O., yellow drab	
Warrensburg, Mo., bluish [...]	

ute Crushing Weight of Columns.

lu. B. Gordon from Results of Experiments of various Authors.

Cast Iron. (*Hodgkinson.*)

Round Solid or Hollow. $\dfrac{36\,a}{1+\dfrac{r^2}{400}} = W.$ *For rectangular put* 500.

Rectangular Solid or Hollow. $\dfrac{36\,a}{1+\dfrac{r^2}{500}} = W.$ For **L, T, U**, etc., put $\dfrac{19\,a}{1+\dfrac{r^2}{900}}.$

Wrought Iron. (*Stoney.*)

Round Solid. $\dfrac{16\,a}{1+\dfrac{r^2}{2400}} = W.$ *Rectangular Solid.* $\dfrac{16\,a}{1+\dfrac{r^2}{3000}} = W.$

Steel. er.)

Round Solid.—Strong steel, $\dfrac{51\,a}{1+\dfrac{r^2}{900}} =$ mild steel, $\dfrac{30\,a}{1+\dfrac{r^2}{1400}} = W.$

Rectangular Solid.—Strong steel, $\dfrac{51\,a}{1+\dfrac{r^2}{1600}} = W;$ mild steel, $\dfrac{30\,a}{1+\dfrac{r^2}{2480}} = W.$

a representing area of metal in sq. ins., r ratio of length to least external diameter or side, and W crushing weight in tons.

Illustration.—What is the crushing weight of a hollow cylindrical column of cast iron 10 ins. in diameter, 20 feet in length, and 1 inch in thickness?

$a =$ area of 10 ins. $-$ area of $\overline{10 - 1 \times 2} = 28.28$ ins. $r = \dfrac{20 \times 12}{10} = 24$, and $24^2 = 576$. Then, $\dfrac{36 \times 28.28}{1+\dfrac{576}{400}} = \dfrac{1018.08}{1+1.44} = 417.25$ *tons* $= 934\,640$ *lbs.*

Note.—This is for hard English iron.

Weight borne with Safety by Solid Cast-iron Columns.

In 1000 *Lbs.*—(*New Jersey Steel and Iron Co.*)

Length. Feet.	Diameter. 2 Ins.	3 Ins.	4 Ins.	5 Ins.	6 Ins.	7 Ins.	8 Ins.	9 Ins.	10 Ins.	11 Ins.	12 Ins.	13 Ins.	14 Ins.	15 Ins.
5	12.4	44	102	184	288	414	560	728	916	1126	1354	—	—	—
6	9.4	36	88	164	264	386	532	698	884	1082	1320	1570	—	—
7	7.2	30	76	146	242	360	502	660	850	1056	1282	1530	1798	2086
8	—	24	66	130	218	332	470	630	812	1016	1240	1486	1754	2040
9	—	20	56	114	198	306	440	596	774	974	1196	1440	1706	[illegible]
10	—	18	48	102	180	282	410	560	739	932	1152	1392	1656	[illegible]
12	—	—	38	80	136	238	354	494	658	846	1056	1292	1550	[illegible]
14	—	—	28	64	122	200	304	432	586	774	966	1192	1440	[illegible]
16	—	—	—	52	100	170	262	378	520	686	878	1094	1332	[illegible]
18	—	—	—	44	84	144	226	332	462	616	796	1000	1228	[illegible]
20	—	—	—	—	72	124	196	292	410	552	720	912	1130	[illegible]

For Tubes or Hollow Columns.

Subtract weight that may be borne by a column, of diameter of internal diameter of tube from external diameter, and remainder will give weight that may be borne. Thickness of metal should not be less than one twelfth diameter of column.

Illustration.—Required the safe load of a solid cast-iron column 6 and 20 feet in length.

er 6 and in a line with 20 is 72, which $\times$ 1000 $=$ 72 000 lbs.

.—This is about one sixth of destructive weight.

Safe Loads as determined by Preceding Formulas.

st Iron, one fifth to one sixth. *Wrought Iron*, one fourth to one fifth. *ls*, one seventh to one tenth.

WOODS.

To Compute Destructive Weight of Column.

inder. $\frac{d^4 .6}{l^2} C = W$. *Rectangle.* $\frac{s^4}{l^2} C = W$. *Short Columns*, or less 30 diameters in length. $\frac{W' \overline{a\,S}}{W' + .75\,\overline{a\,S}} = W$. *d representing diameter and s n ins., a area of section in sq. ins., l length in feet,* S *crushing strength of ma-* , C *coefficient of material, and* W′ *destructive weight, as ascertained by compu- for a long column of like dimensions in lbs.*

Coefficients.

....	22 000	Elm, rock.........	26 000	Red Pine..........	17 500
anadian......	17 000	Fir, Dantzic.......	22 000	Yellow pine.......	12 000
....	17 500	Oak, white........	20 000	White "	9 000
....	14 000	" Eng.	23 000	Spruce...........	14 000
....	17 500	Pitch Pine.........	20 000	Walnut............	12 500

USTRATION.—What is destructive weight of a column of yellow pine 10 ins. e and 12 feet in length or height?

$$\frac{10^4}{12^2} \times 12\,000 = \frac{10\,000}{144} \times 12\,000 = 833\,333 \textit{ lbs.}$$

long square columns of the following: Hodgkinson put C = Dantzic oak, dry, ; red deal, dry, 17 472; and French oak, dry, 15 456.

To Compute Safe Weight in Tons.*

ctangular Oak Columns. Secured at Both Ends. RULE.—Divide length lumn by thickness or least dimension, multiply unit in column C, of wing table, corresponding to this quotient, by width of column, all dimensions in inches; and product will give weight.

C	L/T	C	L/T	C	L/T	C	L/T	C	L/T	C
.43	7	.36	13	.26	19	.18	25	.12	31	.093
.43	8	.35	14	.24	20	.17	26	.12	32	.089
.42	9	.33	15	.23	21	.17	27	.11	33	.084
.4	10	.31	16	.21	22	.15	28	.1	34	.08
.39	11	.29	17	.2	23	.14	29	.098	35	.077
.38	12	.27	18	.19	24	.13	30	.097	36	.073

USTRATION.—Assume a white-oak column, secured at both ends, 12 by 8 ins., o feet in length.

$\times 12 \div 8 = 30$. C for which = .097. Hence, $12 \times 8 \times .097 = 9.312$ *tons*.

other woods take the values in following table. Thus, if an oak column, as , will sustain 9.312 *tons*, the strength of one of yellow pine is thus obtained: 3 : 9.312 :: 3 : 4.816 *tons*.

lative Value of various Woods, their Crushing Strength and Stiffness being Combined.

....	9.4	Elm	5	Mahogany.....	3.7	Yellow pine...	3
sh oak ...	5.8	Beech	4.4	Spruce........	3.6	Sycamore.....	2.6
....	5.1	Quebec oak....	4.1	Walnut	3.4	Cedar.........	1

nparative Value of Long Solid Columns of various Materials. (*Hodgkinson.*)

Iron..... 1000 | Cast Steel.... 2518 | Oak......... 108.8 | Pine.......... 78.5

nce, To compute destructive weight of an Oak or Pine column, take weight f Cast iron of like dimensions, and if for Oak divide by 9, and for Pine b

* All tons, except when otherwise designated, are 2240 lbs.

DEFLECTION.

Deflection of Bars, Beams, Girders, etc.

Experiments of Barlow upon deflection of wood battens determined, that deflection of a beam from a transverse strain, varied directly as cube of length and inversely as breadth and cube of depth, and that with like beams and within limits of elasticity it was directly as the weight.

In bars, beams, etc., of an elastic material, and having great length compared to their depth, deductions of Barlow will apply with sufficient accuracy for all practical purposes; but in consequence of varied proportions of depth to length, of varied character of materials, of irregular resistance of beams constructed with scarphs, trusses, or riveted plates, and of unequal deflection at initial and ultimate strains, it is impracticable to deduce any exact laws regarding degrees of deflection of different and dissimilar figures and proportions.

From an experiment of Mr. Tredgeld it was shown that deflection of cast iron is exactly proportionate to load until stress reaches a certain magnitude, when it becomes irregular.

In experiments of Hodgkinson, it was further shown that sets from deflections were very nearly as squares of deflections.

In a rectangular bar, beam, etc., position of neutral axis is in its centre, and it is not sensibly altered by variations in amount of strain applied. In bars, beams, etc., of cast and wrought iron, position of neutral axis varies in same beam, and is only fixed while elasticity of beam is perfect. When a bar, beam, etc., is bent so as to injure its elasticity, neutral line changes, and continues to change during loading of beam, until its elasticity is destroyed.

When bars, beams, etc., are of same length, deflection of one, weight being suspended from one end, compared with that of a beam *Uniformly Loaded*, is as 8 to 3; and when bars, etc., are supported at both ends, deflection in like case is as 5 to 8. Whence, if a bar, etc., is in first case supported in middle, and ends permitted to deflect, and in second, ends supported, and middle permitted to descend, deflection in the two cases is as 3 to 5.

Of three equal and similar bars or beams, one inclined upward, one downward, at same angle, and the other horizontal, that which has its angle upward is weakest, the one which declines is strongest, and the one horizontal is a mean between the two.

When a bar, beam, etc., is *Uniformly Loaded*, deflection is as weight, and approximately as cube of length or as square of length; and element of deflection and strain upon beam, weight being the same, will be but half of that when weight is suspended from one end.

Deflection of a bar, beam, etc., *Fixed at one End, and Loaded at other*, compared to that of a beam of twice length, *Supported at both Ends, and Loaded in Middle*, strain being same, is as 2 to 1; and when length and loads are same, deflection will be as 16 to 1, for strain will be four times greater on beam fixed at one end than on one supported at both ends; therefore, all other things being same, element of deflection will be four times greater; also, as deflection is as element of deflection into square of length, then, as lengths at which weights are borne in their cases are as 1 to 2, deflection is as $1 : 2^2 \times 4 = 1$ to 16.

Deflection of a bar, beam, etc., having section of a triangle, and supported at ends, is .33 greater when edge of angle is up than when it is down.

r to counteract deflection of a beam, etc., under stress of its load, orizontal surface is required, it should be *cambered* on its upper ual to computed deflection.

Safe Deflection.—One fortieth of an inch for each foot of span, with a factor of safety for load of .33 of destructive weight $= \frac{1}{1440}$, but for ordinary loads and purposes,

Cast Iron, $\frac{1}{1200}$ to $\frac{1}{2000}$; and *Wrought Iron*, $\frac{1}{1600}$ to $\frac{1}{2400}$ or $\frac{1}{1200}$, after beam, etc., has become set.

When Length is uniform, with same weight, deflection is inversely as breadth and square of depth into element of deflection, which is inversely as depth. Hence, other things being equal, deflection will vary inversely as breadth and cube of depth.

ILLUSTRATION.—Deflections of two pine battens, of uniform breadth and depth, and equally loaded, but of lengths of 3 and 6 feet, were as 1 to 7.8.

Deflection of different bars, beams, etc., arising from their own weight, having their several dimensions proportional, will be as square of either of their like dimensions.

NOTE.—In construction of models on a scale intended to be executed in full dimensions, this result should be kept in view.

When a continuous girder, uniformly loaded, is supported at three points by two equal spans, middle portion is deflected downwards over middle bearing, and it sustains by suspension the extreme portions, which also have a bearing on outer bearings. Middle portion is, by deflection, convex upwards, and outer portions are concave upwards; and there is a point of "contrary flexure," where curvature is reversed, being at junction of convex and concave curves, at each side of middle bearing. This point is distant from middle bearing, on each side, one fourth of span. Of remaining three fourths of each span, a half is borne by suspension by middle portion, and a half is supported by abutment. Hence, distribution of load on bearings is easily computed, as given above. Deflection of each span is to that of an independent beam of same length of span as 2 to 5.

In a beam of three equal spans, deflection at middle of either of side spans is to that of an independent beam as 13 to 25.

In a long continuous beam, supported at regular intervals, deflection of each span is to that of an independent beam of one span as 1 to 5.

Cylinder.—If a bar or beam is cylindrical, deflection is 1.7 times that of a square beam, other things being equal.

Formulas for Deflection of Beams of Rectangular Section, etc.

Fixed at One End.

Loaded at One End. $\frac{l^3 W}{b\,d^3 C} = D$; and $\frac{b\,d^3 C D}{l^3} = W$.

" *Uniformly.* $\frac{3\,l^3 W}{8\,b\,d^3 C} = D$; and $\frac{8\,b\,d^3 C D}{3\,l^3} = W$.

Fixed at Both Ends.

Loaded in Middle. $\frac{l^3 W}{24\,b\,d^3 C} = D$; and $\frac{24\,b\,d^3 C D}{l^3} = W$.

" *Uniformly.* $\frac{5\,l^3 W}{8 \times 24\,b\,d^3 C} = D$; and $\frac{8 \times 24\,b\,d^3 C D}{5\,l^3} = W$.

Supported at Both Ends.

Loaded in Middle. $\frac{l^3 W}{16\,b\,d^3 C} = D$; and $\frac{16\,b\,d^3 C D}{l^3} = W$.

" *Uniformly.* $\frac{5\,l^3 W}{8 \times 16\,b\,d^3 C} = D$; and $\frac{8 \times 16\,b\,d^3 C D}{5\,l^3} = W$.

" *at any one Point.* $\frac{m^2 n^2 W}{l\,b\,d^3 C} = D$; and $\frac{l\,b\,d^3 C D}{m^2 n^2} = W$.

Supported in Middle.

Ends Uniformly loaded. $\frac{3\,l^3 W}{5 \times 16\,b\,d^3 C} = D$; and $\frac{5 \times 16\,b\,d^3 C}{3\,l^3} = W$.

l representing length in feet, b breadth, and d depth, both in ins., W ... stres *in lbs., m and n distances of weight between supports*, C *a constant*, ... in *in ins.*

eflection of Beams of Rectangular Section.

Supported at Both Ends.

CAST IRON.

Rectangular Beams. *Loaded in the Middle,* $\frac{l^3 W}{36\,000\, b\, d^3} = D.$

Round Beams. For 36 000 put 24 000.

[ILLUST]RATION.—Assume a rectangular bar of cast iron, 1 inch square and loa[ded with 22]4 lbs., 4.5 feet between its supports.

$$\text{Then } \frac{224 \times 4.5^3}{36\,000 \times 1 \times 1^3} = \frac{20\,412}{36\,000} = .567 \text{ ins.}$$

[By ac]tual experiment of Mr. Hodgkinson the deflection was .561 ins.

WROUGHT IRON.

Rectangular Beams. *Loaded in the Middle,* $\frac{l^3 W}{60\,000\, b\, d^3} = D.$

Round Beams. For 60 000 put 42 000.

WOODS.

Mean of Laslett's, Barlow, etc. (D. K. Clark.)

Supported at Both Ends. Loaded in Middle.

$\frac{l^3 W}{5\, d^3\, C} = D.$ *l representing length in ins. and* W *weight in lbs.*

	C		C		C
[A]sh, Canadian	1476	Iron-wood	4228	Oak, French	2[illegible]
" Eng.	2722	Larch	2100	" white	2[illegible]
[B]eech	2418	Mahogany, Honduras	2118	Pitch pine	2[illegible]
[B]lue Gum	2559	" Mexican	3608	Red "	[illegible]
[E]lm	1227	" Spanish	3360	Rock-elm	[illegible]
Fir, Dantzic	2490	Norway spar	2465	Spruce	
" Memel	3630	Oak, Baltimore	2761	" Amer.	
" Riga	2920	" Canadian	3445	" Scotch	
Greenheart	1888	" Dantzic	2080	Teak	
Iron Bark	4378	" Eng.	1848	Yellow pine	

Application of Table: To Compute Deflection of a Rectangular Beam of W

ILLUSTRATION.—What is the deflection of a floor beam of yellow pine, 3 by [...] 12 feet between its supports, under a uniformly distributed load of 3000 lbs.?

$$C = 2084. \qquad \frac{5 \times 12^3 \times 3000}{8 \times 3 \times 12^3 \times 2084} = \frac{15\,000}{50\,016} = .299 \text{ inch.}$$

Hence, To compute weight that may be borne by a given deflection of such c

$$\frac{8 \times 3 \times 12^3 \times 2084 \times .299}{5 \times 12^3} = \frac{14\,955}{5} = 2991 \text{ lbs.}$$

Deflection of Continuous Girders or Beam[s]

Beams of Uniform Dimensions, Supported at Three or More Be[arings]

(D. K. Clark.)

1. *Two Equal Spans or 3 Bearings.*
Weight on 1st and 3d bearing $= .375\, W\, l$
" " 2d bearing $= 1.25\, W\, l$

2. *Three Equal Spans or 4 [Bearings.]*
Weight on 1st and 4th bearin[g]
" " 2d " 3d "

3. *Four Equal Spans or 5 Bearings.*
[Weight on 1st a]nd 5th bearing $= .39\, W\, l$ | Weight on 2d and 4th bearir[ng]
Weight on 3d bearing $= .93\, W\, l$.

[Cylin]drical Beam. $\frac{l^3 W}{d^4 C} = D$; and $\frac{d^4 C D}{l^3} = W.$

꞉ompute Maximum Load that may be borne by a Rectangular Beam.

tion not to exceed Assigned Limit of one hundred and twentieth of an Inch for each Foot of Span.

Supported at Both Ends. Loaded in Middle.

$= W$. *b and d representing breadth and depth in ins., l length in feet,* C *con-* *ınd* W *weight or load in lbs.*

Constants.

ron	.0003	Oak, white	.027	Oak, red	.039
ht Iron	.0021	Ash, white	.03	Hemlock	.039
y	.018	Pine, pitch	.033	Pine, white	.039
	.024	" yellow	.036	Chestnut, horse	.051

STRATION.—What is maximum load that may be borne by a beam of white by 12 ins., 20 feet between its supports, and loaded in its middle?

$$C = .039. \quad \text{Then } \frac{3 \times 12^3}{20^2 \times .039} = \frac{5184}{15.6} = 332.3 \textit{ lbs.}$$

WROUGHT IRON.

Deflection of Wrought-iron Bars.

Supported at Both Ends. Weight applied in Middle.

FORM.		Length of Bearing.	Breadth.	Depth.	Weight and Deflection by Actual Observation.		at one sixth of Destructive Weight.		at $\frac{1}{125}$th of an Inch for each Foot of Span.		Constant at Reduced Weight and Deflection. $\frac{W\,l^3}{60\,000\,b\,d^3\,D} = C$.
		Feet.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	C
erican.	■	1.83	1	1	600	.06	266	.027	148	.015	1
lish...	"	2.75	2	2	4480	.08	1310	.022	1310	.022	1.29
"	▮	2.75	1.5	2.5	8960	.104	2128	.025	1873	.022	1.25
"	"	2.75	1.5	3	8960	.088	3800	.037	2259	.022	.88

ompute Deflection of, and Weight that may be borne ꞉, a Rectangular Bar or Beam of Wrought Iron.

$$\frac{W\,l^3}{60\,000\,b\,d^3\,D} = C. \qquad \frac{W\,l^3}{60\,000\,b\,d^3\,C} = D. \qquad \frac{60\,000\,b\,d^3\,C\,D}{l^3} = W.$$

STRATION.—What weight will a beam 2 ins. in breadth, 5 ins. in depth, and between its supports, bear with safe deflection of $\frac{1}{125}$ of an inch for each space, or $\frac{1}{1500}$ of its length?

ɔm table $= .88$. $D = \frac{1}{125}$ of $15 = .12$ *inch.*

$$\frac{60\,000 \times 2 \times 5^3 \times .88 \times .12}{15^3} = \frac{1\,584\,000}{3375} = 469.33 \textit{ lbs.}$$

. Clark gives for Elastic deflection, 47 000 for Rectangular bars, and 32 000 for rical.

ꞓ.—Deflection of $\frac{1}{400}$ to $\frac{1}{600}$ of the length may be allowed under special cir- ınces; but under ordinary loads the deflection should not exceed one fourth e, as $\frac{1}{1600}$ to $\frac{1}{2400}$.

tice in U. S. is to allow $\frac{1}{1200}$ after girder has taken its permanent set.

nall bridges there is a slight increase in deflection from high speeds, about .144 of the normal deflection, with the same load moving at slow spee

rge girders there is no perceptible difference between the deflection ꞓ r speeds.

Deflection of Wrought-iron Rolled Beams.

Supported at Both Ends. Weight applied in Middle.

$$\frac{W\,l^3}{70\,000\,d^2\,(4\,a + 1.155\,a')\,D} = \text{C at Reduced Weight and Deflection.}$$

No.	Form.	Length.	Flanges. Width.	Flanges. Mean Thickness.	Web.	Depth.	Weight and Deflection by Actual Observation.		Weight and Deflection at one sixth of Destructive Weight.		C
		Feet.	Ins.	Inch.	Inch.	Ins.	Lbs.	Ins.	Lbs.	Inch.	
1.	I	10	3	.485	.5	7	12 000	.4	3800	.127	1.05
2.	"	20	4.6	.8	.5	9.85	16 000	1.15	6300	.453	.92
3.	"	20	5.7	.643	.6	11.75	20 000	.85	8000	.34	.98

To Compute Deflection of, and Weight that may be borne by, a Wrought-iron Rolled Beam of Uniform and Symmetrical Section.

Supported at Both Ends. Weight applied in Middle. (*D. K. Clark.*)

$$\frac{W\,l^3}{70\,000\,d^2\,(4\,a + 1.155\,a')} = D. \qquad \frac{70\,000\,d^2\,(4\,a + 1.155\,a')\,D}{l^3} = W.$$

l representing span in feet, d reputed depth, or depth less thickness of lower flange in ins., a area of section of lower flange, a' area of section of web for reputed depth of beam, both in sq. ins., and W weight or stress in lbs.

Illustration.—What is deflection of a wrought-iron rolled beam of New Jersey Steel and Iron Co., 10.5 ins. in depth, flanges 5 by .5 ins., and width of web .47 inch, when loaded in its middle with 8000 lbs., and supported over a span of 20 feet?

$d = 10.5 - .5 = 10$ *ins.*, $a = 5 \times .5 = 2.5$ *sq. ins.*, and $a' = 10 \times .47 = 4.7$ *sq. ins.*

$$\text{Then } \frac{8000 \times 20^3}{70\,000 \times 10^2 \times (4 \times 2.5 + 1.155 \times 4.7)} = \frac{64\,000\,000}{107\,999\,500} = .59 \textit{ inch.}$$

If weight is uniformly distributed, divide by 112 500 instead of 70 000.

A like beam 6 ins. in depth, loaded with 2608 lbs., and supported over a span of 12 feet, gave by actual test a deflection of .3 inch, and by above formula it is also .3 inch.

Note.—Deflection for such a beam, for a statical weight or stress of 17 100 lbs., *uniformly distributed*, by rules of N. J. Steel and Iron Co., would be .54 inch, which, with difference in weights, will make deflections alike.

Deflection of Wrought-iron Riveted Beams.

Supported at Both Ends. Weight applied in Middle.

$$\frac{W\,l^3}{168\,000\left(\frac{a + a'}{2} + \frac{a''}{4}\right) d^2\,D} = \text{C at Reduced Weight and Deflection.}$$

No.	Form.	Length.	Flanges.	Angles.	Web.	Depth.	Weight and Deflection by Actual Observation.		Weight and Deflection at one sixth of Destructive Weight.		C
		Feet.	Ins.	Ins.	Inch.	Ins.	Lbs.	Inch.	Lbs.	Inch.	
1.	I	7	—	2.125 × 2 × .28; 2.125 × 2 × .29	.25		4 216	.1	4 062	.096	63
2.	T	11.66	4.5 × .5; 4.5 × .375	2 × 2 × .3125; 2 × 2 × .3125	.25	12.5	77 280	.46	12 880	.075	1.96
			4.5 × .5; 7 × .5	2 × 2 × .375; 3 × 3 × .4375	.375	16.5	115 584	.875	19 265	.148	3.86

To Compute Deflection of, and Weight that may be borne by, a Riveted Beam of Wrought Iron.

$$\frac{W\,l^3}{168\,000\left(\frac{a+a'}{2}+\frac{a''}{4}\right)d^2\,C}=D. \qquad \frac{168\,000\left(\frac{a+a'}{2}+\frac{a''}{4}\right)d^2\,C\,D}{l^3}=W.$$

a, a', and a'' representing areas of upper and lower flanges with their angle pieces, and of web for its entire depth, all in sq. ins.

Note.—If there are not any flanges, as in No. 1, angle pieces alone are to be computed for flange area.

Illustration.—What weight will a riveted and flanged beam of following dimensions sustain, at a distance between its supports of 25 feet, and at a safe deflection of .2 inch or $\frac{1}{1500}$ of its length?

Top flange	$6 \times .5$ *ins.*	Web	.5 *ins.*
Bottom flange	$6 \times .5$ "	Depth	17 "

Angles .... $2.25 \times 2.25 \times .5$ *ins.*

a and a' each $= 6 \times .5 = 3 + \overline{2.25 + 2.25 - .5 \times .5 \times 2} = 7$ *sq. ins.*
$a'' = .5 \times 17 = 8.5$ *sq. ins.* C, as per No. 2, $= .43$, but inasmuch as flanges in this case are much heavier, assume .5.

$$\text{Then } \frac{168\,000\left(\frac{7+7}{2}+\frac{8.5}{4}\right)17^2 \times .2 \times .5}{25^3} = \frac{44\,303\,700}{15\,625} = 2835.4\ lbs.$$

Strength of a Riveted beam compared to a Solid beam is as 1 to 1.5, while for equal weights its deflection is 1.5 to 1.

Tubular Girders. Wrought Iron.

Supported at Both Ends. Weight applied in Middle.

No.	Section.		Length of Bearing.	Breadth.	Depth. Internal.	Depth. External.	Weight.	Deflection.	Deflection at .008 inch for each Foot of Span.	$\frac{l^3 W}{16\,b\,d^3\,D} = C.$
			Feet.	Ins.	Ins.	Ins.	Lbs.	Ins.	Inch.	C
	Thickness	.03 inch	3.75	1.9	2.94	3	448	.1	.03	288
	" "	.525 "	30	15.5	22.95	24	33 685	.56	.24	473
	" top / bottom / sides	.372 " / .244 " / .125 "	30	16	23.28	24	32 538	1.11	.24	224
	" Thickness	.75 "	45	24	34.25	35.75	128 850	1.85	.36	362
	Thickness	.0375 "	17	12	11.925	12	2 755	.65	.136	62.8
	"	.0416 "	17	9.25	13.535	13.62	2 262	.62*	.136	47.9
	"	.143 "	17	9.25	14.714	15	16 800	1.39*	.136	119

*** Destructive weight.**

To Compute Deflection of, and Weight that may be borne by, a Wrought-iron Tubular Girder.

$$\frac{16\,b\,d^3\,C\,D}{l^3}=W. \qquad \frac{W\,l^3}{16\,b\,d^3\,C}=D.$$

Illustration.—What weight may be safely borne by a wrought-iron tube, alike No. 3 in preceding table, for a length of 30 feet, and a deflection of .32 inch?

$$\frac{16 \times 16 \times 24^3 \times 224 \times .24}{30^3} = \frac{190\,253\,629}{27\,000} = 7046\ lbs.$$

Flanged Rails.

Deflection of Iron and Steel Flanged Rails within their elastic ... their transverse strength, is as 17 to 20, and with double-headed

tic ... ...s of *Unsymmetrical Section.*—Elastic strength is ...m ultimate strength, according to ordinary ratio ...ined experimentally. Elastic strength and de... beam of any section is same, whether in its nor... ...side down.

Compar... Strength and Deflection of Cast-iron Flanged Beams.

Description of Beam		Comp. Strength.	Description of Beam.	Comp. Strength.
...of eq...	....	.58	Beam with flanges as 1 to 4.5..	.78
with ...	...nge.	.72	" " " 1 to 5.5..	.82
"	...2....	.63	" " " 1 to 6 ..	1
" "	...4....	.73	" " " 1 to 6.73	.92

SHAFTS.

To Compute Deflection and Distributed Weight for Limit of Deflection.

Wrought Iron.

Deflection. — *Weight.*

	Supported at Ends.		Fixed at Ends.	Supported at Ends.		Fixed at Ends.
Round.	$\frac{W\,l^3}{66\,400\,d^4}$	and	$\frac{W\,l^3}{133\,000\,d^4} = D.$	$\frac{664\,d^4}{l^2}$	and	$\frac{1330\,d^4}{l^2} = W.$
Square.	$\frac{W\,l^3}{97\,500\,s^4}$	and	$\frac{W\,l^3}{195\,000\,s^4} = D.$	$\frac{975\,s^4}{l^2}$	and	$\frac{1950\,s^4}{l^2} = W$

Cast Iron.

Round.	$\frac{W\,l^3}{39\,400\,d^4}$	and	$\frac{W\,l^3}{79\,000\,d^4} = D.$	$\frac{394\,d^4}{l^2}$	and	$\frac{790\,d^4}{l^2} =$
Square.	$\frac{W\,l^3}{58\,000\,s^4}$	and	$\frac{W\,l^3}{116\,000\,s^4} = D.$	$\frac{580\,s^4}{l^2}$	and	$\frac{1160\,s^4}{l^2} =$

Steel.

Round.	$\frac{W\,l^3}{78\,800\,d^4}$	and	$\frac{W\,l^3}{158\,000\,d^4} = D.$	$\frac{788\,d^4}{l^2}$	and	$\frac{1576\,d^4}{l^2}$
Square.	$\frac{W\,l^3}{116\,000\,s^4}$	and	$\frac{W\,l^3}{232\,000\,s^4} = D.$	$\frac{1160\,b^4}{l^2}$	and	$\frac{2320\,b}{l^2}$

d representing diameter and s side of shaft, in ins., l length between centres ...ings, in feet, and W *weight in lbs.*

Deflection of a Cylindrical Shaft from its Weight when Supported at Both Ends.

$.007\,318\,\frac{l^4}{d^2\,C} = D.$ *l representing length in feet, d diameter in ins., a ...stant, ranging from* 475 *to* 550.

The greatest admissible deflection for any diameter is $.001\,67\,\frac{l}{d} = D.$ $\sqrt[3]{.91}$

Admissible Distances between Bearings.

Diam. of Shaft.	Distance. Wrought Iron.	Distance. Steel.	Diam. of Shaft.	Distance. Wrought Iron.	Distance. Steel.	Diam. of Shaft.	Wrou... Iro...
Ins.	Feet.	Feet.	Ins.	Feet.	Feet.	Ins.	Fee...
1	12.27	12.61	5	20.99	21.57	9	25.[illegible]
2	15.46	15.84	6	22.3	22.92	10	26[illegible]
[illegible]	17.7	18.19	7	23.48	24.13	11	27[illegible]
[illegible]	[illegible]8	20.02	8	24.55	25.23	12	2[illegible]

...Ends of Shaft are rigidly connected at Ends... ...sults obtained by above formula; but ... D = .25 of above.

Deflection of Mill and Factory Shafts.

$\frac{l^3 W}{\pi d^4 C} = D.$ *l representing length between supports in ins.*, W *weight at middle bs., d diameter of shaft in ins., and* C *as follows:*

Bessemer steel.......... 3 800 000	Wrought iron............ 3 500 000

To Compute Deflection of a Cylindrical Shaft.

Rule.—Divide square of three times length in feet by product of follow-; *Constants* and square of diameter in ins., and quotient will give deflection.

t iron, cylindrical............	1500	Wrought iron, cylindrical....	1980
" square................	2560	" " square............	3360

Example.—Length of a cast-iron cylindrical shaft is 30 feet, and its diameter in tre 15 ins.; what is its deflection?

$$\frac{\overline{30 \times 3}^2}{1500 \times 15^2} = \frac{8100}{337\,500} = .024 \text{ ins.}$$

SPRINGS.

Flexure of a spring is proportional to its load and to cube of its length.

Deflection of a Carriage Spring.

A railway-carriage spring, consisting of 10 plates .3125 inch thick, and 2 .375 inch, length 2 feet 8 ins., width 3 ins., and *camber* or spring 6 ins., lected as follows, without any permanent set:

ton.........	.5 inch.	1.5 tons..........	1.5 ins.	3 tons.............	3 ins.
"	1 "	2 "	2 "	4 "	4 "

Compression of an India-rubber Buffer of 3 Ins. Stroke.

ton..........	1.3 ins.	2 tons..........	2 ins.	5 tons.........	2.75 ins.
tons.........	1.75 "	3 "	2.375 "	10 "	3 "

General Deductions.

Deflection depends essentially upon form of Girder, Beam, etc.

A continuous weight, equal to that a beam, etc., is suited to sustain, will cause deflection of it to increase unless it is subjected to considerable nges of temperature.

Heaviest load on a railway girder should not exceed .16 of that of de-ctive weight of girder when laid on at rest.

Semi-girders or Beams.—Deflection of a beam, etc., fixed at one end and led at other, is 32 times that of same beam supported at both ends and led in middle.

Deflection consequent upon Velocity of Load.—Deflection is very much in-ised by instantaneous loading; by some authorities it is estimated to be ibled.

Momentum of a railway train in deflecting girders, etc., is greater than ct from dead weight of it, and deflection increases with velocity.

When motion is given to load on a beam, etc., point of greatest deflection s not remain in centre of beam, etc., as beams broken by a travelling load always fractured at points beyond their centres, and often into several ces.

Heaviest running weight that a bridge is subjected to is ... tive and tender, which is equal to 2 tons per lineal foot.

Girders should not, under any circumstances, be deflecte h to a foot in length.

Deflection of Solid rolled beams compared to Riveted beams is as 1 to 1.5.

Wrought-iron Girders of ordinary construction are not safe when sub-cted to violent impacts or disturbances, with a load equal to .33 of their :structive weight.

Wood.—In consequence of wood not being subjected to weakening by the fect of impact, a factor of safety of 5 for single pieces is held to be suffi-ent, but for structures, in consequence of loss of strength in its connections, factor of from 8 to 10 becomes necessary.

Working Strength or Factors of Safety.*

Elastic strength of materials is, in general terms, half of its ultimate de-tructive or breaking strength. If a working load of .5 elastic strength, or 25 of ultimate strength, be accepted, equal range for fluctuation within lastic limit is provided. But, as bodies of same material are not all uni-'orm in strength, it is necessary to observe a lower limit than .25 where naterial is exposed to great or to sudden variations of load or stress.

Cast Iron.—Mr. Stoney recommends .25 of ultimate tensile strength, for lead weights; .16 for bridge girders; and .125 for crane posts and machin-ry. In compression, free from flexure, cast iron will bear 8 tons (17920 bs.) per sq. inch; for arches, 3 tons (6720 lbs.) per sq. inch; for pillars, upporting dead loads, .16 of ultimate strength; for pillars subject to 'ibration from machinery, .125; and for pillars subject to shocks from eavy-loaded wagons and like, .1, or even less, where strength is exerted in esistance to flexure.

Wrought Iron.—For bars and plates, 5 tons (11200 lbs.) per sq. inch of et section is taken as safe working tensile stress; for bar iron of extra uality, 6 tons (13440 lbs.). In compression, where flexure is prevented, tons (8960 lbs.) is safe limit; in small sizes, 3 tons (6720 lbs.). For col-mns subject to shocks, Mr. Stoney allows .16 of calculated breaking weight; rith quiescent loads, .25. For machinery, .125 to .1 is usually practised; nd for steam-boilers, .25 to .125.

Mr. Roebling claims that long experience has proved, beyond shadow of doubt, that good iron, exposed to a tensile strain not above .2 of its ulti-mate strength, and not subject to strong vibration or torsion, may be de-ended upon for a thousand years.

Steel.—A committee of British Association recommended a maximum working tensile stress of 9 tons (20160 lbs.) per sq. inch. Mr. Stoney rec-mmends, for mild steel, .25 of ultimate strength, or 8 tons (17920 lbs.) per q. inch. Limit for compression must be regulated very much by nature of teel, and whether it be annealed or unannealed. Probably a limit of 9 tons 20160 lbs.) per sq. inch, same as limit for tension, would be safe max-mum for general purposes. In absence of experience, Mr. Stoney further ecommends that, for steel pillars, an addition not exceeding 50 per cent. hould be made to safe load for wrought-iron pillars of same dimensions.

Wood.—One tenth of ultimate stress is an accepted limit. Piles have, in ome situations, borne permanently .2 of their ultimate compressive strength.

Foundations.—According to Professor Rankine, maximum pressure on oundations in firm earth is from 17 to 23 lbs. per sq. inch; and, on rock, it hould not exceed .125 of its crushing load.

Masonry.—Mr. Stoney asserts that working load on rub rick-work, or concrete rarely exceeds .16 of crushing weight mass; and that this seems to be a safe limit. In an arch, calcu hould not exceed .05 of crushing pressure of stone.

* Essentially from Manual of D. K. Clark, London, 1877.

Ropes.—For round, working load should not exceed .14 and for flat .11.

Perfect material and workmanship....

Dr. Rankine gives following factors: { Good ordinary material and workmanship... { Metal........ Wood........ Masoury.....

A *Dead Load* is one that is laid on very gradually an

A *Live Load* is one that is laid on suddenly, as a loa passing swiftly over a bridge.

DETRUSIVE OR SHEARING STRE

Detrusive or Shearing Strength of any body is dire or thickness, or area of shearing surface.

Results of Experiments upon Detrusiv Metals with a Punch.

Metals.	Diameter of Punch.	Thickness of Metal.	Power exerted.
	Ins.	Ins.	Lbs.
Brass....................	1	.045	5 448
Cast iron..................	—	—	—
Copper..................	.5	.08	3 983
	1	.3	21 250
Steel....................	.5	.25	34 720
" Bessemer...........	.875	.75	103 600
			184 800
Wrought iron...........	.5	.17	11 950
	1	.615	82 870
	2	1.06	297 400

To Compute Power to Punch Iron, Bra

RULE.—Multiply product of diameter of punch and th 150 000 if for wrought iron, by 128 000 if for brass, a cast iron or copper, and product will give power require

EXAMPLE.—What power is required to punch a hole .5 inch of brass .25 inch thick? $.5 \times .25 \times 128\,000 = 16\,000$ *lbs.*

Comparison between Detrusive and Strengths.

Assuming compression and abrasion of metal in appli one inch in diameter to extend to .125 of an inch beyond comparative resistance of wrought iron to *detrusive* an latter estimated at 600 lbs. per sq. inch, for a bar 1 foot in

WOODS.

Detrusive Strength of Woods. Pe

	Lbs.		Lbs.		Lbs
Spruce..........	470	Pine, pitch...	510	Ash.........	65
Pine, white......	490	Hemlock.....	540	Chestnut.....	69

To Compute Length of Surface of Resis to Horizontal Thrust.

RULE.—Divide 4 times horizontal thrust in lbs. by pr wood in ins., and detrusive resistance per sq. inch in lbs. and quotient will give length required.

EXAMPLE.—Thrust of a rafter is 5600 lbs., breadth of tie bea pine, is 6 ins.; what should be length of beyond score for raft

As ... th 510 as above. Then $\frac{4 \times 5600}{6 \times 510} = \frac{22\,400}{3060} =$

Shearing.

Wrought Iron.

esistance to shearing of American is about 75 per cent., and of English ›er cent., of its tensile strength.

:esistance to shearing of plates and bolts is not in a direct ratio. It ap- ximates to that of square of depth of former, and to square of diameter atter.

tesults of Experiments upon Shearing Strength of Various Metals by Parallel Cutters.

Wrought Iron.—Thickness from .5 to 1 inch, 50 000 lbs. per sq. inch.

Made by Inclined Cutters, angle = 7°.

PLATES.	Thickness.	Power.	BOLTS.	Diam.	Power.
	Ins.	Lbs.		Ins.	Lbs.
ss	.05	540	Brass	1.11	29 700
per	.297	11 196	Copper	.775	11 310
:l	.24	14 930	Steel	.775	28 720
›ught iron	.51	39 150	Wrought iron	.32	3 093
	1	44 800		1.142	35 410

›sult of Experiments in Shearing, made at U. S. Navy Yard, Washington, on Wrought-iron Bolts.

am.	Stress. Minimum.	Maximum.	Per Sq. Inch.	Diam.	Stress. Minimum.	Maximum.	Per Sq. Inch.
ch.	Lbs.	Lbs.	Lbs.	Inch.	Lbs.	Lbs.	Lbs.
5	8 900	9 400	44 149	.875	25 500	27 600	41 503
75	18 400	19 650	39 553	1	32 900	35 800	40 708

Mean 41 033 lbs.

tesult of Experiments on .875 Inch Wrought-iron Bolts. (*E. Clark.*)

	Lbs.	Tons.		Lbs.	Tons.
gle shear	54 096	24.15	Double shear of two .625-inch plates		
uble "	46 904	22.1	riveted together (one section)	45 696	20.4

Tensile strength........ 50 176 lbs.

Riveted Joints.

Experiments on strength of riveted joints showed that while the plates re destroyed with a stress of 43 546 lbs., the rivets were strained by a ess of 39 088 lbs.

Cast Iron.

Resistance to shearing is very nearly equal to its tensile strength. An erage of English being 24 000 lbs. per sq. inch.

Steel.

Shearing strength of steel of all kinds (including Fagersta) is about 72 per it. of its tensile strength.

Treenails.

Oak treenails, 1 to 1.75 ins. in diameter, have an average shearing strength 1.8 tons per sq. inch, and in order to fully develop their strength, the planks o which they are driven should be 3 times their diameter.

Woods.

When a beam or any piece of wood is let in (not mortised) at n to another piece, so that thrust will bear in direction of fibr at is cut, depth of cut *at right angles to fibres* should not be m length of piece, fibres of which, by their cohesion, resist thrust.

TENSILE STRENGTH.

Tensile Strength is resistance of the fibres or particles of a body to separation. It is therefore proportional to their number, or to area of its transverse section, and in metals it varies with their temperature, generally decreasing as temperature is increased. In silver, tenacity decreases more rapidly than temperature; and in copper, gold, and platinum less rapidly.

Cast Iron.

Experiments on Cast-iron bars give a tensile strength of from 4000 to 5000 lbs. per sq. inch of its section, as just sufficient to balance elasticity of the metal; and as a bar of it is extended the 12 300th part of its length for every 1000 lbs. of direct strain, or one sixteenth of an inch in 64.06 feet per sq. inch of its section, it is deduced that its elasticity is fully excited when it is extended less than the 2400th part of its length, and extension of it at its limit of elasticity, which is about .5 of its destructive weight, is estimated at 1500th part of its length.

Average ultimate extension is 500th part of its length.

A bar will contract or expand .000 006 173 inch, or the 162 000th of its length, for each degree of heat; and assuming extreme of moderate range of temperature in this country 140° (— 20° + 120°), it will contract or expand with this change .000 864 2 inch, or the 1157th part of its length.

It follows, then, that as 1000 lbs. will extend a bar the 12 300th part of its length, contraction or extension for 1157th part will be equivalent to a force of 10 648 lbs. (4.75 tons) per sq. inch of section. It shrinks in cooling from one eighty-fifth to one ninety-eighth of its length.

Mean tensile strength of American, as determined by Maj. Wade for U. S. Ordnance Corps, is 31 829 lbs. (14.21 tons) per sq. inch of section; mean of English, as determined by Mr. E. Hodgkinson for Commission on Application of Iron to Railway Structures, 1849, is 19 484 lbs. (8.7 tons); and by Col. Wilmot, at Woolwich, in 1858, for gun-metal, is 23 257 lbs. (10.35 tons). varying from 12 320 lbs. (5.5 tons) to 25 520 lbs. (10.5 tons).

Mean ultimate extension of four descriptions of English, as determined for Commission above referred to, was, for lengths of 10 feet, .1997 inch, being 600th part of its length; and this weight would compress a bar the 775th part of its length.

Tensile strength of strongest piece ever tested—45 970 lbs. (20.52 tons). This was a mixture of grades 1, 2, and 3 from furnace of Robert P. Parrott at Greenwood, N. Y., and at 3d fusion.

At 2.5 tons per sq. inch it will extend same as wrought iron at 5.6 tons.

From experiments of Maj. Wade he deduced the following mean results:

Density.	Tensile.	Transverse.	Torsion.	Crushing.	Hardness.
7.225	31 829	8182	8614	144 916	22.34

Tensile per sq. inch of section; *Transverse* per sq. inch, one end fixed, …pplied at other end at a distance of 1 foot; and *Torsion* per sq. inch, …plied at end of a lever 1 foot in length.

…gs are 6 per cent. stronger than dry, and 30 per cent. but when castings are chilled and annealed, a gain of …d over those made in green sand.

…sile stress is for American as 4.55 to 1, and …ngth increasing with density.

elting.—Strength, as well as density, are increased by repeated re-
gs. The increase is the result of the gradual abstraction of the con-
t carbon of the iron, and the consequent approximation of the metal
ught iron.
ılt of the 4th melting of pig iron, as determined by Major Wade, was
ease its strength from 12880 lbs. (5.75 tons) to 27888 lbs. (12.45
ınd its specific gravity from 6.9 to 7.4.

e successive meltings of Greenwood iron, N. Y., gave tensile strength
oo, 30100, and 35700 lbs.

ılt of 5th melting by Mr. Bramwell was to increase strength of Acadian
om 16800 lbs. (7.5 tons) to 41440 lbs. (18.5 tons).

ıelting increases its resistance to a crushing stress from 70 to 80 tons
r cent.) per sq. inch of section.

Hot and Cold Blast.

Hodgkinson deduced from experiments that relative strength of 1.2
ins. square was as 100, 80, and 77, and that hot blast had less tensile
th than cold blast, but greater resistance to a crushing stress.

tain James ascertained that tensile strength of .75 inch bars, cut out
ıd 3 inch bars, had only half strength of a bar cast 1 inch square.

Robert Stephenson concluded, from experiments of recent date, that
ge strength of hot blast was not much less than that of cold blast; but
old blast, or mixtures of cold blast, were more regular, and that mixt-
f cold blast and hot blast were better than either separate.

Stirling's Mixed or Toughened Iron.

mixture of a portion of malleable iron with cast iron, carefully fused
rucible, a tensile strain of 25764 lbs. has been attained. This mixt-
hen judiciously managed and duly proportioned, increases resistance
t iron about one third; greatest effect being obtained with a propor-
f about 30 per cent. of malleable iron.

Malleable Cast Iron.

ısile strength of annealed malleable is guaranteed by some Manufact-
of it at 56000 lbs.; it is capable of sustaining 22400 lbs. without per-
ıt set.

Wrought Iron.

periments on English bars gave a tensile strength of from 22000 lbs.
400 lbs. per sq. inch of its section, as just sufficient to balance elasticity
metal; and as a bar of it is extended the 28000th part of its length
ery 1000 lbs. of direct strain, or one sixteenth of an inch in 116.66 feet
q. inch of its section, it is deduced that its elasticity is fully excited
it is extended the 1000th part of its length, and extension of it at its
of elasticity, which is from .45 to .5 of its destructive weight, is esti-
l at 1520th part of its length.

ar will expand or contract .000006614 inch, or 151200 part of its length
ıch degree of heat; and assuming, as before stated for cast iron, that
me range of temperature in air in this country is 140°, it will contract
pand with this change .000926, or 1080th of its length, which is eq
o a force of 20740 lbs. (9.25 tons) per sq. inch of section.

an tensile strength of American bars and plates (45000 to 7(
0 lbs. (27 tons) per sq. inch of section; as determined by Prof. Jo
36, is 55900 lbs.; and mean of English, as determined by Capt. E
w, Brunel, and Fairbairn, is 53900 lbs.; and by Mr. Kirkaldy, ba
(47040 to 55910) 51475 lbs. (22.97 tons).

Greatest strength observed 73 449 lbs. (32.79 tons).

Ultimate strength, as given by Mr. D. K. Clark, 59 732 lbs. (26.66 tons).

Average ultimate extension is 600th part of its length.

Strength of plates, as determined by Sir William Fairbairn, is fully 9 per cent. greater with fibre than across it.

Resistance of wrought iron to crushing and tensile strains is, as a mean, as 1.5 to 1 for American; and for English 1.2 to 1.

Reheating.—Experiments to determine results from repeated heating and laminating, furnished following:

From 1 to 6 reheatings and rollings, tensile stress increased from 43 904 lbs. to 61 824 lbs., and from 6 to 12 it was reduced to 43 904 again.

Effect of Temperature.—Tensile strength at different temperatures is as follows: 60°, 1; 114°, 1.14; 212°, 1.2; 250°, 1.32; 270°, 1.35; 325°, 1.41; 435°, 1.4.

Experiments of Franklin Institute gave at

80°	56 000 lbs.	720°	55 000 lbs.	1240°	22 000 lbs.
570°	66 500 "	1050°	32 000 "	1317°	9 000 "

Annealing.—Tensile strength is reduced fully 1 ton per sq. inch by annealing.

Cold Rolling.—Bars are materially stronger than when hot rolled, strength being increased from one fifth to one half, and elongation reduced from 21 to 8 per cent.

Hammering increases strength in some cases to one fifth.

Welding.—Strength is reduced from a range of 3 to 44 per cent. 20 per cent., or one fifth, is held to be a fair mean.

Temperature.—From 0° to 400° strength is not essentially affected, but at high temperature it is reduced. When heated to redness its strength is reduced fully 25 per cent.

Tensile strength at 23° was found to be .024 per cent. less than at 64°.

Cutting Screw Threads reduces strength from 11 to 33 per cent.

Hardening in water, oil, etc., reduces elongation, but does not essentially increase the strength.

Case Hardening reduces strength fully 10 per cent.

Galvanizing does not affect strength of plates.

Angled Bars, etc.—Their strength is fully 10 per cent. less than for bolts and plates.

Elements connected with Tensile Resistance of various Substances.

Substances.	Stress per Sq. Inch for limit of Elasticity.	Ratio of Stress to that causing Rupture.	Substances.	Stress per Sq. Inch for limit of Elasticity.	Ratio of Stress to that causing Rupture.
	Lbs.			Lbs.	
Beech	3 355	.3	Wrought iron, ordinary	17 600	.3
Cast iron, English	4 000	.22	" " Swedish	24 400	.34
" " American	5 000	.2	" " English	18 850	.35
Oak	2 856	.23		22 400	.35
'teel plates, .5 inch	52 000	.62	" " American	15 000	.36
wire	75 700	.5	" wire, No. 9, unannealed	47 532	.46
	3 332	.23	" " " annealed	36 300	.45

ving outer surface does not reduce the strength of bolts.

TIE-RODS.

esults of Experiments on Tensile Strength of Wrought-iron Tie-rods.

Common English Iron, 1.1875 Ins. in Diameter.

Description of Connection.	Breaking Weight.
	Lbs.
micircular hook fitted to a circular and welded eye............	14 000
o semicircular hooks hooked together.........................	16 220
ght-angled hook or goose-neck fitted into a cylindrical eye......	29 120
o links or welded eyes connected together.....................	48 160
raight rod without any connective articulation.................	56 000

Ratio of Ductility and Malleability of Metals.

In order of 'ire-drawing Ductility.	In order of Laminable Ductility.	In order of Wire-drawing Ductility.	In order of Laminable Ductility.	In order of Wire-drawing Ductility.	In order of Laminable Ductility.
old.	Iron.	Tin.	Gold.	Tin.	Zinc.
ilver.	Copper.	Lead.	Silver.	Platinum.	Iron.
latinum.	Zinc.	Nickel.	Copper.	Lead.	Nickel.

Relative resistance of Wrought Iron and Copper to tension and compreson is as 100 to 54.5.

Steel.

Experiments of Mr. Kirkaldy, 1858-61, give an average tensile strength r bars of 134 400 lbs. (60 tons) per sq. inch for tool-steel, and 62 720 lbs. 8 tons) for puddled. Greatest observed strength being 148 288 lbs. (66.2 ns). Plates, mean, 86 800 lbs. (32 to 45.5 tons) with fibre, and 81 760 lbs. 36.5 tons) across it.

Its resistance to crushing compared to tension is as 2.1 to 1.

Hardening.—Its strength is very materially increased by being cooled in il, ranging from 12 to 55 per cent.

Crucible.—Experiments by the Steel Committee of Society of Civil ngineers, England, 1868-70, give a tensile strength of 91 571 lbs. per sq. ch (40.88 tons), with an elongation of .163 per cent., or 1 part in 613, and 1 elastic extension of .000 034 7th part for every 1000 lbs. per sq. inch, or part in 28 818.

Bessemer.—Experiments by same Committee give a tensile strength 76 653 lbs. per sq. inch (34.22 tons) with an elongation of .144 per cent., r 1 part in 695, and an elastic extension of .000 034 82d part for every 1000 s. per sq. inch, or 1 part in 28 719.

Result of Experiments by Committe of Society of Civil Engineers of England, 1868-70, and Mr. Daniel Kirkaldy, 1875.

Per Sq. Inch.

Steel.	Elastic Strength.		Elastic Extension in Parts of Length.	Elastic Extension per 1000 Lbs.	Ratio of Elastic to Ultimate Strength	Destructive Weight.
	Lbs.	Tons.	Per Cent.	In Length.	Per Ce	Tons.
rucible.............	49 840	22.25	.225	.000 5	58.	
essemer...........	44 800	20	.204	.000 45	59	
agersta, unannealed.	48 608	21.7	—	—	59.	
" annealed....	39 200	17.5	—	—	51.	
emens, unannealed..	32 080	14.56	—	—	46.	
" annealed....	28 784	12.85	—	—	44.	

Average Tensile Elasticity of Steel Bars and Plates.

(Com. of Civil Engineers, 1870.)

Description.	Elasticity per Sq. Inch.	Elastic Extension in Parts of Length.	Ratio of Elastic to Destructive Strength.
Bars.	Lbs.	Parts.	Per Cent.
Crucible, hammered and rolled..........	50 557	1 in 485	58.2
Bessemer, " "	43 814	1 in 675	55
Fagersta, rolled	56 560	—	64.8
" unannealed....................	34 048	—	55.6
" hammered and rolled..........	55 574	—	64.7
" " " annealed.......	40 858	—	54
" plates, unannealed............	30 710	1 in 980	59.2
" " annealed	26 940	1 in 1020	56.5
Siemens, " unannealed............	32 500	—	46.4
" " annealed..............	28 780	—	44.4
" tires	40 174	—	58.8
Krupp's shaft.........................	42 112	1 in 185	—

Tensile strength of steel increases by reheating and rolling up to second operation, but decreases after that.

Tensile Strength of Various Materials, deduced from Experiments of U. S. Ordnance Department, Fairbairn, Hodgkinson, Kirkaldy, and by the Author.

Power or Weight required to tear asunder One Sq. Inch, in Lbs.

Metals.	Lbs.
Antimony, cast.................	1 053
Bismuth, cast..................	3 248
Cast Iron, Greenwood..........	45 970
" mean, Major Wade...	31 829
" gun-metal, mean....	37 232
" malleable, annealed..	56 000
" Eng., strong.........	29 000
" " weak..........	13 400
" " averages.....	15 600 21 280
" " gun-metal......	23 257
" " mean*........	19 484
" " Low Moor, No. 2	14 076
" " Clyde, No. 1....	16 125
" " " No. 3....	23 468
" " Stirling, mean..	25 764
Copper, wrought...............	34 000
" rolled.................	36 000
" cast...................	24 250
" bolt...................	36 800
" wire	61 200
Gold..........................	20 384
Lead, cast	1 800
" pipe.....................	2 240
" " encased	3 759
" rolled sheet..............	3 320
Platinum wire.................	53 000
Silver, cast	40 000
~l, cast, maximum...........	142 000
" mean...............	88 560
uddled, maximum.......	173 817
r. Tool Co............	179 980
......	210 000 300 000
....	96 300
...	93 700
..	180 000

Metals.	Lbs.
Steel, Pittsburgh, mean.........	94 450
" Bessemer, rolled........	76 650 125 000
" " hammered.....	152 900
" Eng., cast................	134 000
" " " plates, mean....	93 500
" " plates..............	86 800
" " puddled plates......	62 720
" " crucible............	91 570
" " homogeneous.......	96 280
" " blistered, bars......	104 000
" " Fagersta bars.......	89 600
" " " plates.....	98 560
" " Whitworth's......	89 600 152 000
" " Siemens's plates..	64 900 69 880
" " Krupp's shaft......	92 243
Tin, cast.......................	5 000
" Banca.....................	2 100
Wire rope, per lb. w't per fathom	4 480
" " galvanized steel, "	6 720
Wrought Iron, boiler plates...	45 500 62 000
" rivets	65 000
" bolts, mean.........	60 500
" " inferior......	30 000
" hammered.........	54 000
" shaft..............	44 750
" wire...............	73 600
" " No. 9..........	100 000
" " No. 20.........	120 000
" " diam. .0069 inch	301 168
" " galv'ized .058 "	64 960
" Eng., heavy forging.	33 600
" " plates, lengthw'e	53 800
" " " crosswise	48 800

* application of

Metals.	Lbs.
rought Iron, Eng., mean	51 000
" Eng., Low Moor	57 600
" " Lancashire	48 800
" " Thames	65 920
" " armor-plates	40 000
" " bar	31 300 / 56 000
" " " charcoal	63 000
" " rivet, scrap	51 760
" Russian, bar, best	59 500
" " "	49 000
" Swedish, " best	72 000
" " "	48 900
inc	3 500
" sheet	7 000 / 16 000

Alloys or Compositions.	
lloy, Cop. 60, Iron 2, Zinc 35, Tin 2	85 120
" Tin 10, Antimony 1	11 000
luminium, Cop. 90	71 600
" maximum	96 320
ell-metal	3 670
rass, cast	18 000
" wire	49 000
ronze, Phosphor., extreme	50 915
" " mean	34 464
" ordinary	23 500
" Cop. 10, Tin 1	33 000
" " 9, " 1	38 080
" " 8, " 1	36 000
" " 2, Zinc 1	29 000
un-metal, ordinary	18 000
" mean	33 600
" bars	42 040
peculum metal	7 000
ellow metal	48 700

Woods.	
sh, white	14 000
" American	9 500
" English	16 000
amboo	6 300
ay	14 000
eech, English	11 500
irch	15 000
" Amer., black	7 000
ox, African	23 000
ullet	19 000
edar, Lebanon	11 400
" West Indian	7 500
" American	11 600
hestnut	12 500
" horse	10 000
ypress	6 000
eal, Christiana	12 400
bony	27 000
m	6 000 / 13 000
m, blue	18 000
" Alabama	15 860
ackmatack	12 000
ickory	11 000
olly	16 000
ance	17 350 / 23 000

Woods.	Lbs.
Larch	4 200 / 9 500
Lignum vitæ	11 800
Locust	16 000 / 20 500
Mahogany, Honduras	21 000
" Spanish	8 000 / 12 000
Oak, Pa., seasoned	20 333
" Va., "	25 222
" white	16 500
" live, Ala.	16 380
" red	10 250
" African	9 500
" English	4 500 / 7 571
" Dantzic	4 200
Pear	9 860
Pine, Va.	19 200
" Riga	14 000
" yellow	13 000
" white	11 800
" red	13 000
Poon	13 300
Poplar	7 000
Redwood, Cal.	10 833
Spruce, white	10 290 / 12 400
Sycamore	9 600 / 13 000
Teak, India	15 000
" African	21 000
Walnut, Eng.	7 800
" black	16 633
" Mich.	17 580
Willow	13 000
Yew	8 000
Across Fibre.	
Oak	2 300
Pine	550

Miscellaneous.	
Basalt, Scotch	1 469
Beton, N. Y. Stone Con'g Co.	300 / 500
Blue stone	77
Brick, extreme	750
" inferior	100 / 290
Cement, Portland, 7 days	400 / 860
" " pure, 1 mo.	393
" " sand 2, 320 days	713
" " " 1 "	948
" " pure, "	1 152
" " sand 1, in water 1 mo.	201
" " " 1 " 1	[illegible]
" " " 3, 1 ye	
" " " 5, 1	
" " " 7, 1	
" Hydraulic	
" Rosedale, Ulst. Co.	
" " sand 1,	
" " 9 mos.	

Miscellaneous.	Lbs.	Miscellaneous.
Cement, Roman, in water 7 days.	90	Mortar, 1 year.............
" " " 1 mo...	115	
" " " 1 year.	286	" hydraulic..........
" " sand 1, 42 days..	284	
" " " 2, " ..	199	" ordinary..........
" " " 3, " ..	160	Oxhide..................
Flax...........................	25 000	Rope, Manila..............
Glass, crown....................	2 546	" tarred hemp.........
Glue...........................	4 000	Sandstone.................
Granite.........................	578	" fine green.......
Gutta Percha.....................	3 500	" Arbroath.......
Hemp rope....................	12 000 / 16 000	" Caithness.......
Ivory...........................	1 000	
Leather belting..................	330	" Portland........
Limestone....................	670 / 2 800	" Craigleth........
Marble, statuary.................	3 200	Silk fibre..................
" Italian..................	5 200	Slate......................
Marble, white....................	9 000	
" Irish....................	17 600	Whalebone................

TORSIONAL STRENGTH.

SHAFTS AND GUDGEONS.

Shafts are divided into *Shafts* and *Spindles*, according to nitude, and are subjected to Torsion and Lateral Stress com Lateral Stress alone.

A *Gudgeon* is the metal journal or *Arbor* upon which a w revolves.

Lateral Stiffness and Strength.—Shafts of equal length have *ness* as their breadth and cube of their depth, and have *latera* their breadth and square of their depths.

Shafts of different lengths have *lateral stiffness* directly as t and cube of their depth, and inversely as cube of their lengtl *lateral strength* directly as their breadth and as square of thei inversely as their length.

Hollow Shafts having equal lengths and equal quantities of n *lateral stiffness* as square of their diameter, and have *lateral stre* diameters. Hence, in hollow shafts, one having twice the dia other will have four times the stiffness, and but double the st when having equal lengths, by an increase in diameter they inc ness in a greater proportion than in strength.

When a solid shaft is subjected to torsional stress, its centre axis, about which both intensity and leverage of resistance incre or side; and the two in combination, or moment of resistance crease as square of radius or side.

und Shaft.—Radius of ring of resistance is radius of gyr sing alike to that of a circular plate revolving on its axi The ultimate moment of resistance then is expresse nal area of shaft, by ultimate shearing resistance pe by radius, and by .7071.

$.7854\,d^2\,r\,S \times .7071 = .278\,d^3\,S = R\,W.$ (*D. K. Clar*

eter of shaft and r radius, S *ultimate shearing* , R *radius through which stress is applied, in ctive stress, in lbs.*

$\frac{R\,W}{.278\,d^3} = S$; and $\sqrt[3]{\frac{R\,W}{S}} \times 1.534 = d.$

d Shaft.—Strength, compared to a square of equal sectional area, t as 1 to .85. Diameter of a round section, compared to side of section of equal resistance, is as 1 to .96.

re Shaft.—Moment of torsional resistance of a square shaft exceeds a round of same sectional area, in consequence of projection of cor- square; but inasmuch as material is less disposed to resist torsional he resistance of a square shaft, compared to a round one of like area on, is as 1 to 1.18, and of like side and diameter, as 1.08 to 1.

, $\frac{.278 \times 1.08\, s^3\, S}{R} = W.$ *Hollow Round Shafts.* $\frac{.278\,(d^4 - d'^4)\, S}{R\, d} = W.$

Section is comparatively Thin. $\frac{1.57\, d^2\, t\, S}{R} = W.$ *s representing side, external and internal diameters, and t thickness of metal in ins.*

onal Angle of a bar, etc., under equal stress, will vary as its length. torsional strength of bars of like diameters is inversely as their

upon a shaft from a weight upon it is proportional to product of the parts multiplied into each other. Thus, if a shaft is 10 feet in length, and a weight ntre of gravity of the stress is at a point 2 feet from one end, the parts 2 multiplied together, are equal to 16; but if weight or stress were applied in of the shaft, parts 5 and 5, multiplied together, would produce 25.

load upon a shaft is uniformly distributed over any part of it, it is consid- united in middle of that part; and if load is not uniformly distributed, it is red as united at its centre of gravity.

tion of a shaft produced by a load which is uniformly distributed over its s same as when .625 of load is applied at middle of its length.

tance of body of a shaft to lateral stress is as its breadth and square lepth; hence diameter will be *as product of length of it, and length one side of a given point, less square of that length.*

TRATION.—Length of a shaft between centres of its journals is 10 feet; what be relative cubes of its diameters when load is applied at 1, 2, and 5 feet e end? and what when load is uniformly distributed over length of it?

$l \times l^1 - l^2 = d^3$; and when uniformly distributed, $d^3 \div 2 = d^1$.

$1 = 10 - 1^2 = 9 =$ *cube of diameter at 1 foot;* $10 \times 2 = 20 - 2^2 = 16 =$ *cube eter at 2 feet;* $10 \times 5 = 50 - 5^2 = 25 =$ *cube of diameter at 5 feet.*

a load is uniformly distributed, stress is greatest at middle of length, and to half of it; $25 \div 2 = 12.5 =$ *cube of diameter at 5 feet.*

ional Strength of any square bar or beam is as cube of its side, and linder as cube of its diameter. Hollow cylinders or shafts have great- ional strength than solid ones containing same volume of material.

Compute Diameter of a Solid Shaft of Cast or Wrought Iron to Resist Lateral Stress alone.

n Stress is in or near Middle. RULE.—Multiply weight by len— of n feet; divide product by 500 for cast iron and 560 for wrou be root of quotient will give diameter in ins.

IPLE.—Weight of a water-wheel upon a cast-iron shaft is 50 000 lbs., and centre of stress of wheel 7 feet from one end; what should be ody?

$\sqrt[3]{\left(\frac{50\,000 \times 30}{500}\right)} = 14.42$ *ins., if weight was in middle of its length*

e diameter at 7 feet from one end will be, as by preceding Rule, 3 1 = *relative cube of diameter at 7 feet;* $30 \times 15 - 15^2 = 225 =$ *relati eter at 15 feet, or at middle of its length.*

as $\sqrt[3]{225} : 14.42 :: \sqrt[3]{161} : 12.89$ *ins., diameter of shaft at 7 feet from one*

For Bronze, 420; Cast steel, 1000 to 1500; and Puddled steel, 50(

When Stress is uniformly laid along Length of Shaft. RULE.- cube root of product of weight and length by 9.3 for Cast iron for Wrought iron, and quotient will give diameter in ins.

EXAMPLE.—Apply rule to preceding case. $\frac{\sqrt[3]{50\,000 \times 30}}{9.3} = 12.31$ *ins.*

For Bronze, 8.5; Cast steel, 18.6 to 27.9; and Puddled steel, 9.3.

When Diameter for Stress applied in Middle is given. RULE.—T root of .625 of cube of diameter, and this root will give diameter re

EXAMPLE.—Diameter of a shaft when stress is uniformly applied along is 14.42 ins.; what should be its diameter, stress being applied in middle?

$$\sqrt[3]{.625 \times 14.42^3} = \sqrt[3]{.625 \times 3000} = 12.33 \textit{ ins.}$$

To Compute Diameter of a Solid Shaft of Cast I Resist its Weight alone.

RULE.—Multiply cube of its length by .007, and square root of will give diameter in ins.

EXAMPLE.—Length of a shaft is 30 feet; what should be its diameter in

$$\sqrt{(30^3 \times .007)} = \sqrt{189} = 13.75 \textit{ ins}$$

HOLLOW SHAFTS.

To Compute Diameter of a Hollow Shaft of Cas to Sustain its Load in Addition to its Weig

When Stress is in or near Middle. RULE.—Divide continued p .012 times cube of length, and number of times weight of shaft in square of internal diameter added to 1, and twice square root of added to internal diameter will give whole diameter in ins.

EXAMPLE.—Weight of a water-wheel upon a hollow shaft 30 feet in len times its own weight, and internal diameter is 9 ins.; what should be wh eter of shaft?

$$2\sqrt{\left(\frac{.012 \times 30^3 \times 2.5}{1+9^2}\right)} + 9 = 2\sqrt{\frac{810}{82}} = 6.28 \textit{ ins.}, \text{ and } 6.28 + 9 = 15.2$$

To Compute Diameter of a Round or Square Sl Resist Combined Stress of Torsion and Wei

RULE.—Multiply extreme of pressure upon crank-pin, or at pit pinion, or at centre of effect upon the blades of a water-wheel, et shaft may at any time be subjected to; by length of crank or wheel, etc., in feet; divide the product by *Coefficient* in following T cube root of quotient will give diameter of shaft or its journal in in

$$\text{Or, } \sqrt[3]{\frac{P\,R}{C}} = d.$$

EXAMPLE.—What should be diameter for journal of a wrought-iron w shaft, extreme pressure upon crank-pin being 59 400 lbs., and crank 5 feet

$$C = 120. \quad \sqrt[3]{\frac{59\,400 \times 5}{120}} = \sqrt[3]{2475} = 13.53 \textit{ ins.}$$

When Two Shafts are used, as in Steam-vessels, etc., with On RULE.—Divide three times cube of diameter for one shaft by cube root of quotient will give diameter of shaft in ins.

$$\text{Or, } \sqrt[3]{\frac{3\,d^3}{4}} = d.$$

—Area of journal of a shaft is 113 ins.; what should be dia

$$? \; 113 = 12. \quad \text{Then } \frac{3 \times 12^3}{4} = 1296, \text{ and } \sqrt[3]{1296} =$$

Torsional Strength of Various Metals.

Vm. Wade, U. S. Ordnance Corps, 1851, *Steel Committee* [*England*, 1868], *and Stevens Institute, N. J.*, 1878.)

Reduced to a Uniform Measure of One Inch in Diameter or Side.
Stress applied at One Foot from Axis of Body and at Face of Axis.

s and Metals.	Tensile Strength.	Destructive Stress at 25 Ins.	Destructive Stress Computed at 12 Ins.	Torsional Strength $\frac{WR}{d^3}=T$.	Coefficient $\frac{C\,d^3}{R}=W$. 2 Ins.	5 Ins.	10 Ins.	15 Ins.	20 Ins.
'ast Iron.	Lbs.	Lbs.	Lbs.						
)iam. {1.3 ins. / .65 in.} Area 1 sq. inch	45 000	520	1082	499	100	95	90	85	8c
ım. {3.25 ins. / 2.61 "} rea 2.97 sq. ins.	"	3800	7904	230	45	40	35	30	25
)iam. = 1.9 ins. Least...	9 000	1550	3664	530	130	125	120	115	110
Mean ...	31 829	2145	4462	650					
Greatest.	45 000	2840	5907	850					
ide 1 inch.... Area 1 sq. inch	"	350	728	728	125	120	115	10	105
:ought Iron.									
)iam. = 1.9 ins. Least ...	38 027	1250	2600	376	120	[illegible]	110	105	10c
Mean....	56 300	1375	2860	416					
Greatest.	74 592	1500	3120	452					
Area 2.83 sq. ins.									
Bronze.									
ım. = 9 ins. Least....	17 698	500	1040	152	30	28	26	—	—
Greatest.	56 786	650	1352	197	38	36	34	—	—
Area 2.83 sq. ins.									
ast Steel.									
ım. =) ins. Least....	42 000	2600	5408	788	160	155	550	—	—
Greatest.	128 000	7760	16140	2353	475	470	465	—	—
Area 2.83 sq. ins.									
semer Steel.									
ım. = 1.382 ins. \ rea 1.5 sq. ins.	36 960	1568	3261	1236	245	240	235	230	225

Compute Diameter of Shafts of Oak and Pine.

tiply diameter ascertained for Cast Iron as follows: Oak by 1.83, ' Pine by 1.716.

Metals and Woods.

mate Torsional Strength.—Of Cast Iron may be taken as equal to its erse strength for American and .9 for English, or as .26 of its tensile th for American and .23 for English. Of Wrought Iron, as .7 to .8 of nsverse strength for American and .7 to 1 for English, and of Steel. as its tensile strength.

stic Torsional Strength.—Of Cast Iron may be taken as equal to its 'erse strength, of Wrought Iron 40 per cent. of its ultimate torsic ;th, of Steel 44 per cent. of its tensile strength, and 45 per cent. of ıte torsional strength.

semer Steel.—Has a torsional strength of 6670 lbs. per sq. inch at a f one foot, being somewhat less than that of Cast Iron, Fagersta ha. nt. of its ultimate transverse strength, and Siemens 44.5 per cent. imate tensile.

NOTE.—Examples here given are deduced from instances of successful practice; where diameter has been less, fracture has almost universally taken place, stress being increased beyond ordinary limit.

2.—When shafts of less diameter than 12 ins. are required, *Coefficients* here given may be slightly reduced or increased, according to quality of the metal and diameter of shaft; but when they exceed this diameter, *Coefficients* may not be increased, as strength of a shaft decreases very materially as its diameter increases.

Order of shafts, with reference to degree of torsional stress to which they may be subjected, is as follows:

1. Fly-wheel. | 2. Water-wheel. | 3. Secondary shaft. | 4. Tertiary, etc.

Hence, diameters of their journals may be reduced in this order.

To Compute Diameter of a Wrought-iron Centre Shaft for connecting Two Engines at a Right Angle.

Conditions of such a shaft are as follows:

Greatest stress that it is subjected to is when leading engine is at .75 of its stroke, and following engine .25 of its stroke; hence, position of each crank is as sin. $22^\circ\ 30' \times 2 = .7071$ of length of crank or radius of power.

Consequently, $\sqrt[3]{\dfrac{2\,P\,.707\,R}{125}} = d$. P *representing extreme pressure on piston.*

NOTE.—In computing P it is necessary to take very extreme pressure that piston may be subjected to, however short the period of time. Average pressure does not meet requirement of case.

ILLUSTRATION.—Extreme pressure upon each piston of two engines connected at a right angle was 111 592 lbs., and stroke of pistons 10 feet; what should have been diameter of centre shaft? and what of each wheel or driving shaft?

$$\sqrt[3]{\left(\frac{111\,592 \times 2 \times .707\ \frac{10}{2}}{125}\right)} = \sqrt[3]{\frac{788\,955}{125}} = 18.42 \textit{ ins. centre shaft.}$$

For ordinary mill purposes, driving shafts should be as cube root of .75 cube of centre shaft.

$$\text{Thus } \sqrt[3]{\frac{18.48^3 \times 3}{4}} = 16.79 \textit{ ins.}$$

To Compute Torsional Strength of Hollow Shafts and Cylinders.

RULE.—From fourth power of exterior diameter subtract fourth power of interior diameter, and multiply remainder by *Coefficient* of material; divide this product by product of exterior diameter and length or distance from axis at which stress is applied in feet, and quotient will give resistance in lbs.

$$\text{Or, } \frac{(d^4 - d'^4)\,C}{d\,l} = R.$$

EXAMPLE.—What torsional stress may be borne by a hollow cast-iron shaft, having diameters of 3 and 2 ins., power being applied at one foot from its axis?

$$C = 130. \quad 3^4 - 2^4 \times 130 = 8450, \text{ which} \div 3 \times 1 = \frac{8450}{3} = 2816.6 \textit{ lbs.}$$

To Compute Torsional Strength of Round and Square Shafts.

RULE.—Multiply Coefficient in preceding Table by cube of side or of diameter of shaft, etc., and divide product by distance from axis at which stress is applied in feet; quotient will give resistance in lbs.

ILLUSTRATION.—What torsional stress may be borne by a cast-iron shaft of best material, 2 ins. in diameter, power applied at 2 feet from its axis.

$$\text{Table} = 130. \quad \frac{130 \times 2^3}{2} = \frac{1040}{2} = 520 \textit{ lbs.}$$

…eeling of vessel or roughness of sea the stress may …e, diameter of journal of its shaft should be equal

GUDGEONS.

Compute Diameter of a Single Gudgeon of Cast Iron, to Support a given Weight or Stress.

LE.—Divide square root of weight in lbs. by 25 for Cast iron, and 26 'rought iron, and quotient will give diameter in ins.

MPLE.—Weight upon a gudgeon of a cast-iron water-wheel shaft is 62 500 lbs.; should be its diameter?

$$\frac{\sqrt{62\,500}}{25} = \frac{250}{25} = 10 \textit{ ins.}$$

Compute Diameter of Two Gudgeons of Cast Iron, to Support a given Stress or Weight.

LE.—Proceed as for two shafts, page 792.

Compute Ultimate Torsional Strength of Round and Square Shafts. (*D. K. Clark.*)

ıst Iron. *Round.* $\frac{.278\, d^3\, S}{R} = W$; $1.534\sqrt[3]{\frac{W\,R}{S}} = d$; and $\frac{W\,R}{278\, d^3} = S$.

re. $\frac{.4\, s^3\, S}{R} = W$, and $1.36\sqrt[3]{\frac{W\,R}{S}} = s$. *Hollow.* $\frac{.278\,(d^4 - d'^4)\,S}{R\,d} = W$.

epresenting ultimate shearing strength, and W *moment of load, both in lbs.,* s *side uare shaft, and* R *radius of stress, both in ins.*

USTRATION.—What is ultimate torsional strength of a round cast-iron shaft in diameter, stress applied at 5 feet from its axis?

ıume S = 20 000 lbs. Then $\frac{.278 \times 4^3 \times 20\,000}{5 \times 12} = 5930$ *lbs.*

experiments of Major Wade, ordinary foundry iron has a torsional strength ?5 lbs., or 644 lbs. per sq. inch at radius of one foot.

ıs, take preceding illustration. Then $\frac{7725 \times 4^3}{5 \times 12} = 8240$ *lbs.*

'rought Iron. *Round.* $\frac{.2224\, d^3\, S}{R} = W$. *Square.* $\frac{.32\, s^3\, S}{R} = W$.

hen Torsional Strength per sq. inch for radius of 1 inch is ascertained, itute C for .278, .4, .2224, or .32.

'ess which will give a bar a permanent set of .5° is about .7 of that h will break it, and this proportion is quite uniform, even when strength aterial may vary essentially.

rought Iron, compared with Cast Iron, has equal strength under a stress h does not produce a permanent set, but this set commences under a less ' in wrought iron than cast, and progresses more rapidly thereafter. ngest bar of wrought iron acquired a permanent set under a less strain a cast-iron bar of lowest grade.

rongest bars give longest fractures.

teel. *Round.* $\frac{.2\, d^3\, S}{R} = W$. When S is not known, substitute for S 72 s = 72 per cent. of tensile strength.

rsional Strength of Cast Steel is from 2 to 3 times that of Cast Iron

llowing rules are purposed to apply in all instances to dian als of shafts, or to diameter or side of bearings of beams, et h of journal or distance upon which strain bears does not gr diameter of journal or side of beam, etc.; hence, when length or atly increased, diameter or side must be correspondingly incre

fficients for torsional breaking stress of Iron, Bronze, and Stee. ined by Major Wade, are: Wrought Iron, 640; Cast Iron, 560; Cast Steel, 1120 to 1680. Puddled Steel does not differ essentially of cast iron

Formulas for Minimum and Maximum Diam. of Wrought-iron Shafts.

(*A. E. Seaton, London,* 1883, *and Board of Trade, Eng.*)

Compound Engines. $\sqrt[3]{\frac{D^2\, p\, d^2\, 15}{C}}\, S = diameter$. D *and d representing diameter of low and high pressure cylinders, and* S *half stroke, all in ins., p pressure of steam in boiler, in lbs. per sq. inch, and* C *a coefficient, as follows:*

Angle of Crank.	Shafts. Crank.	Shafts. Propeller.	Angle of Crank.	Shafts. Crank.	Shafts. Propeller.	Angle of Crank.	Shafts. Crank.	Shafts. Propeller.	Angle of Crank.	Shafts. Crank.	Shafts. Propeller.
90°	2468 / 4000	2880 / 5400	100°	2279 / 4000	2659 / 5400	110°	2131 / 4000	2487 / 5400	120°	2016 / 4000	2352 / 5400

$\sqrt[3]{\frac{IHP}{r}}\, C = diameter$. *A. E. Seaton, London,* 1883.

Side-wheel Engines, Sea Service.—One cylinder crank journal, C = 80; outboard 100; Two cylinder crank journal 50; outboard 65; and centre shaft 58.

Propeller Engines.—One cylinder crank journal 150; Tunnel 130; Two cylinder compound crank 130; Tunnel 110; Two cranks, crank 100; Tunnel 85; Three cranks, crank 90; and Tunnel 78.

River Service.—C may be reduced one fifth.

Illustration.—With a compound propeller engine, steam cylinders 20 and 40 ins. in diameter, by 40 ins. stroke, operating under a pressure of 80 lbs. steam (mercurial gauge), what should be the diameter of the shafts of wrought iron?

$$\sqrt[3]{\frac{20^2 \times 80 + 40^2 \times 15}{4000}} \times 40 = \sqrt[3]{\frac{56\,000}{4000}} \times 40 = 8.24 \textit{ ins. crank shaft;}$$

$$\text{and } \sqrt[3]{\frac{56\,000}{5400}} \times 40 = 7.46 \textit{ ins. propeller shaft.}$$

Journals of Shafts, etc.

Journals or bearings of shafts should be proportioned with reference to pressure or load to be sustained by the journal. Simplest measure of bearing capacity of a journal is product of its length by its diameter, in sq. ins.; and axial area or section thus obtained, multiplied by a *coefficient* of pressure per sq. inch, will give bearing capacity.

Sir William Fairbairn and Mr. Box give instances of weights on bearings of shafts, etc., from which following deductions are made, showing pressure per sq. inch of axial section of journal:

Crank pins, 687 to 1150 lbs. per sq. inch.

Link bearings, 456 to 690 lbs. per sq. inch.

Pressure on bearings, as a general rule, should not exceed 750 lbs. per sq. inch of axial area.

Length of Journals should be 1.12 to 1.5 times diameter.

Journals of Locomotives or Like Axles are usually made twice diameter, and to sustain a pressure of 300 lbs. per sq. inch of axial area, or 10 sq. ins. per ton of load.

Solid Cylindrical Couplings or Sleeves.

$d + \sqrt{5.5\, d} = D$; $3\, d = L$; $.8\, d = l$; $.25\, d + .12 = k$. *d representing diameter, and* L *length of sleeve, l length of lap or scarf of shaft, k breadth of key, its depth being half its breadth, and* D *diameter of coupling or sleeve, all in ins.*

Flanged Couplings.

$+ \sqrt{3.5\, d} = D$; $3\, d + 1 = F$; $.3\, d + .4 = l$; $d + 1 = L$; $l \div 4 = s$. D *representing diameter of body of coupling,* F *diameter of flanges, l thickness of both flanges, of each coupling, s projection of end of one shaft and retrocession of other ...re of coupling, and d diameter of shaft, all in ins.*

Supports for Shafts. (*Molesworth.*)

...presenting distance of supports apart, in feet.

Resist Lateral Stress. $\sqrt[3]{\frac{L\,W}{C}} = D$. W *representing weight or pressure re of length in lbs., and* D *diameter or side, if square, in ins.*

e of C.—Wrought Iron, 560; Cast Iron, 500; Cast Steel, 1000 to 1500; Bronze, nd Wood, 40. When Weight is distributed put 2 C.

s of C *for Shafting of Various Metals, as observed by different uthorities, and deduced from Formulas of Navier.* $\frac{16\,W\,r}{\pi\,d^3} = C$.

Ultimate Resistance.

METAL.	C	METAL.	C	METAL.	C
UGHT IRON.		CAST IRON.		STEEL.	
an, Pemb^e, Me.	61 673	American, mean	36 846	American, Conn..	82 926
Ulster....	61 815		38 300	" Spindle	102 131
mean.....	66 436		42 821	" Nash. I. Co.	95 213
h, refined.....	49 148	" 18 trials	44 957	English, Shear....	111 191
"	54 585	English, mean..	22 132	Bessemer......	73 060
h............	61 909		38 217		79 662

Mill and Factory Shafts. (*J. B. Francis.*)

Cylindrical.

$\frac{W\,R}{d^3} = T$. $\frac{\pi\,d^3\,T}{16\,R} = W$.

Square.

$\frac{3\sqrt{2}\,W\,R}{s^3} = T$. $\left(\frac{s^3\,T}{R} \div 3\right) \div \sqrt{2} = W$.

Mean value of T.

ron........	22 000 / 65 000	Wrought Iron....	49 000 / 94 000	Steel...........	76 000 / 111 000
mean......	35 000	" mean.....	50 000	" mean.........	86 000
" Eng.	30 000	" " Eng.	45 000	" " Bessemer	78 000

STRATION.—What is the ultimate or destructive weights that may be borne ound Cast-iron shaft 2 ins. in diameter, and by a Square shaft 1.75 ins. side, applied at 25 ins. from axis? Assume T = 36 000.

Round.

$$\frac{16 \times 2^3 \times 36\,000}{16 \times 25} = 2261.95 \text{ lbs.}$$

Square.

$$\left(\frac{1.75^3 \times 36\,000}{25} \div 3\right) \div \sqrt{2} = 1819.1 \text{ lbs.}$$

ir lengths should be reduced, and diameter increased, in following cases: At high velocities, to admit of increased diameter of journals, thereby ing them less liable to heating. 2d. As they approach extremity of a f shafting. 3d. Attachment of intermediate pulleys or gearing.

Prime Movers of Power. *Transmitters of Power.*

ght i. $\sqrt[3]{\frac{100\,IHP}{n}} = d$, and $.01\,n\,d^3 = IHP$. $\sqrt[3]{\frac{50\,IHP}{n}} = d$, and $.02\,n\,d^3 = IHP$.

$\sqrt[3]{\frac{62.5\,IHP}{n}} = d$, and $.016\,n\,d^3 = IHP$. $\sqrt[3]{\frac{31.25\,IHP}{n}} = d$, and $.032\,n\,d^3 = IHP$.

$\sqrt[3]{\frac{167\,IHP}{n}} = d$, and $.006\,n\,d^3 = IHP$. $\sqrt[3]{\frac{83.5\,IHP}{n}} = d$, and $.012\,n\,d^3 = IHP$.

representing horse-power transmitted, n number of revolutions, and d diameter ft in ins.

STRATION 1.—What should be diameter of a wrought-iron s nit 128 IP at 100 revolutions per minute?

$$\sqrt[3]{\frac{50 \times 128}{100}} = \sqrt[3]{\frac{6400}{100}} = 4 \textit{ ins.}$$

What IP will a steel shaft of 4 ins. diameter transmit at 100 e?

$$.032 \times 100 \times 4^3 = 204.8 \textit{ horses.}$$

TRANSVERSE STRENGTH.

Transverse or Lateral Strength of any Bar, Beam, Rod, etc., is in proportion to product of its breadth and square of its depth; in like-sided bars, beams, etc., it is as cube of side, and in cylinders as cube of diameter of section.

When One End is Fixed and the Other Projecting, strength is inversely as distance of weight from section acted upon; and stress upon any section is directly as distance of weight from that section.

When Both Ends are Supported only, strength is 4 times greater for an equal length, when weight is applied in middle between supports, than if one end only is fixed.

When Both Ends are Fixed, strength is 6 times greater for an equal length, when weight is applied in middle, than if one end only is fixed.

When Ends Rest merely upon Two Supports, compared to one *When Ends are Fixed*, strength of any bar, beam, etc., to support a weight in centre of it, is as 2 to 3.

When Weight or Stress is Uniformly Distributed, weight or stress that can be supported, compared with that when weight or stress is applied at one end or in middle between supports, is as 2 to 1.

Metals.

In Metals, less dimension of side of a beam, etc., or diameter of a cylinder, greater its proportionate transverse strength, in consequence of their having a greater proportion of chilled or hammered surface, compared to their elements of strength, resulting from dimensions alone.

Strength of a *Cylinder*, compared to a *Square* of like diameter or sides, is as 5.5 to 8. Strength of a *Hollow Cylinder* to that of a *Solid Cylinder*, of same area of section, is about as 1.65 to 1, depending essentially upon the proportionate thickness of metal compared to diameter.

Strength of an *Equilateral Triangular Beam, Fixed at One End and Loaded at the Other*, having an *edge up*, compared to a *Square* of the same area, is as 22 to 27; and strength of one, having an *edge down*, compared to one with an *edge up*, is as 10 to 7.

NOTE.—In Barlow and other authors the comparison in this case is made when the beam, etc., rested upon *supports*. Hence the stress is contrariwise.

Strongest rectangular bar or beam that can be cut out of a cylinder is one of which the squares of breadth and depth of it, and diameter of the cylinder, are as 1, 2, and 3 respectively.

Cast Iron.

Mean transverse strength of American, as determined by Major Wade, is 681 lbs. per sq. inch, suspended from a bar fixed at one end and loaded at the other; and mean of English, as determined by Fairbairn, Barlow, and others, is 500 lbs.

Experiments upon bars of cast iron, 1, 2, and 3 ins. square, give a result of transverse strength of 447, 348, and 338 lbs. respectively; being in the ratio of 1, .78, and .756.

Woods.

Beams of wood, when laid with their annular layers vertical, are stronger than when they are laid horizontal, in the proportion of 8 to 7.

Relative Stiffness of Materials to Resist a Transverse Stress.

... .089	Cast Iron.... 1	Oak.......... .095	Wrought iron 1.3
.. .073	Elm......... .073	White pine... .1	Yellow pine. .0[illegible]

ngth of a Rectangular Beam in an *Inclined position*, to resist a vertical is to its strength in a horizontal position, as square of radius to square ine of elevation; that is, as square of length of beam to square of dis- between its points of support, measured upon a horizontal plane.

Transverse Strength of Various Materials.

Ordnance Department, Hodgkinson, Fairbairn, Kirkaldy, and by the Author.)

reduced to uniform Measure of One Inch Square, and One Foot in Length; Weight suspended from one End.

METALS.

....	260
on, mean of 4 grades	660
" (Maj. Wade)........	681
ordinary	575
extreme, West P't F'dry	980
gun-metal,* " "	740
Eng., Low Moor, cold blast..	472
" Ponkey, "	581
" Ystalyfera "	770
" mean, 65 kinds	500
" " 15 kinds, cold blast	641
" planed bar..........	518
" rough bar...........	534
....	244
hammered, mean...........	1500
cast, soft..................	1540
" hard...................	4200
hematite, hammered........	1620
Krupp's shaft..............	2096
Fagersta, hammered........	1200
ht Iron, mean..............	600
" English............	475
" Swedish†..........	665

WOODS.

....	220
glish........................	160
nada........................	120
n, Canada..................	87
....	130
vhite........................	112
....	160 115
white.......................	160
Cuba......................	63 105
nut.........................	160
....	125
anada, red	170
altic, mean..................	153
anada, yellow..............	58 117
" red.....................	120
orway......................	123
antzic......................	163
iga.........................	112
lemel.......................	161
" red	75
heart, Guiana..............	160
blue........................	136
natack......................	102
ck..........................	100

WOODS.

Hickory..........................	170 250
Iron wood, Burmah...............	240
Larch, Russian	118
Lignumvitæ......................	162
Locust	295
Mahogany........................	112
Mangrove	162
Maple............................	202
Oak, white	150
" live	160
" red, black....................	135
" African......................	207
" English.....................	105 157
" French......................	160
" Dantzic......................	88
" Canada......................	146
" Sardinia.....................	142
" Spanish	105
Pine, white.......................	125
" pitch	137
" yellow.......................	130
" Georgia......................	200
Poon.............................	184
Poplar...........................	112
Spruce, Canada...................	125
" black.....................	87
Sycamore	125
Tamarack	100
Teak.............................	165
Walnut...........................	112
Willow...........................	87
Whitewood.......................	116

STONES, BRICKS, ETC.

Brick, common, mean............	20
" pressed, "	40
" English, stock..............	11.8
" " fine	14
Brick arch........................	15
Cement, mean	15
" " Portland.........	10.2 37.5
" "	5
" " rtland.	5
" "	2
" Puz ...	4.5
" Port	8
" Ron.	2.5
Concrete, Eng	
ce	

* This was with a tensile strength of 27000 lbs.

† With 840 lbs. the deflection was 1 inch, and the elasticity of

Stones, Bricks, etc.	
Concrete, Eng., fire-brick, sand 3, lime 1	.7
" Eng., clay and chalk	5.4
Flagging, blue, New York	31.25
Freestone, Conn.	13
" Dorchester	10.8
" New Jersey, mean	19
" New York	24
" Eng., Craigleth	10.7
" " Darby, Victoria	1.3
" " Park Spring	4.3
Glass, flooring	42.5
Granite, blue, coarse	18
" Quincy	26
" mean	25
" Eng., Cornish	22
Limestone	
" English	11
Marble, Vermont, mean	92

Stones, Bricks, etc.	
Marble, Adelaide	45
" Italian, white	116
Mortar, lime, 60 days	25
" 1 lime, 1 sand	2
" 1 " 2 "	1.75
" 1 " 4 "	1.25
Oolite, English, Portland	21.2
Paving, Scotch, Caithness	68
" Ireland, Valentia	68.5
" Welsh	157
" English, Yorkshire, blue	10.4
" " Arbroath	17
Slate	81
" Bangor	90
" English, Llangollen	43
Stones, English, Bath	5.2
" " Kentish, Rag	35.8
" " Yorkshire, landing	22.5
" Caen	12.5

Elastic Transverse Strength of Woods, compared with their Breaking Weight, is as follows:

	Per Cent.		Per Cent.		Per Cent.
Ash	29	Norway Spruce	30	Red Pine	29
Beech	25	Oak, Dantzic	36	Riga Fir	30
Elm	32	" English	33	Teak	32
Larch	38	Pitch Pine	24	Yellow Pine	30

Increase in Strength of several Woods by Seasoning.

Per Cent.

Ash......44.7 | Beech......61.9 | Elm......12.3 | Oak.....26.1 | White pine....9

Concretes, Cements, etc.

Materials.	Breaking Weight.	Materials.	Breaking Weight.
	Lbs.		Lbs.
CONCRETES (English).		BRICKS (English).	
Fire-brick beam, Portl'd cement	3.1	Best stock	11.8
" sand 3 parts, lime 1 part	.7	Fire-brick	14
CEMENTS (English).		New brick	10.7
Blue clay and chalk	5.4	Old brick	9.1
Portland	37.5 10.2	Stock-brick, well burned	5.8
		" inferior, burned	2.5
Sheppey	5		

Transverse Strength of Various Figures of Cast Iron.

Reduced to Uniform Measure of Sectional Area of One Inch Square and One Foot in Length. Fixed at one End; Weight suspended from the other.

Form of Bar or Beam.	Breaking Weight.	Form of Bar or Beam.	Breaking Weight.
	Lbs.		Lbs.
		Rectangular prism.	
Square	673	2 × .5 ins. in depth	1456
		" 3 × .33 " in depth	2392
		" 4 × .25 " in depth	2652
Square, diagonal vertical	568	Equilateral triangle, an edge up	560
'ylinder	573	Equilateral triangle, an edge down	958
		2 ins. in depth × 2 × .268 inch in width	2068
w cylinder; greater neter twice that of er	794	2 ins. in depth × 2 × .268 inch in width	555

lid and Hollow Cylinders of various Materials.

e Foot in Length. Fixed at one End; Weight suspended from the other.

RIALS.	External Diam.	Internal Diam.	Breaking Weight.	MATERIALS.	External Diam.	Internal Diam.	Breaking Weight.
DS.	Ins.	Inch.	Lbs.	METAL.	Ins.	Ins.	Lbs.
......	2	—	685	Cast iron, cold blast	3	—	12000
......	2	1	604				
......	2	—	772	STONE-WARE.			
pine..	1	—	75	Rolled pipe of fine clay.....	2.87	1.928	190
" ..	2	—	610				

* An inch-square batten, from same plank as this specimen, broke at 139 lbs.

ulas for Transverse Stress of Rectangular Bars, Beams, Cylinders, etc.

Fixed at One End. Loaded at the Other.

, Beams, etc. $\frac{l\,W}{b\,d^2} = S$; $\frac{S\,b\,d^2}{l} = W$; $\frac{S\,b\,d^2}{W} = l$; $\frac{l\,W}{S\,d^2} = b$; $\sqrt{\frac{l\,W}{S\,b}} = d$;

and Cylinder $\sqrt[3]{\frac{l\,W}{S}} = b$ *and* d.

Fixed at Both Ends. Loaded in Middle.

, Beams, etc. $\frac{l\,W}{6\,b\,d^2} = S$; $\frac{6\,S\,b\,d^2}{l} = W$; $\frac{6\,S\,b\,d^2}{W} = l$; $\frac{l\,W}{6\,S\,d^2} = b$;

$\sqrt{\frac{l\,W}{6\,S\,b}} = d$; and Cylinder $\sqrt[3]{\frac{l\,W}{6\,S}} = b$ *and* d.

Fixed at Both Ends. Loaded at any Other Point than in Middle.

, Beams, etc. $\frac{2\,m\,n\,W}{3\,l\,b\,d^2} = S$; $\frac{3\,l\,b\,d^2\,S}{2\,m\,n} = W$; $\frac{2\,m\,n\,W}{3\,S\,b\,d^2} = l$; $\frac{2\,m\,n\,W}{3\,S\,l\,d^2} = b$;

$\sqrt{\frac{2\,m\,n\,W}{3\,S\,l\,b}} = d$; and Cylinder $\sqrt[3]{\frac{2\,m\,n\,W}{3\,S\,l}} = b$ *and* d.

Supported at Both Ends. Loaded in Middle.

, Beams, etc. $\frac{l\,W}{4\,b\,d^2} = S$; $\frac{4\,S\,b\,d^2}{l} = W$; $\frac{4\,S\,b\,d^2}{W} = l$; $\frac{l\,W}{4\,S\,d^2} = b$,

$\sqrt{\frac{l\,W}{4\,S\,b}} = d$; and Cylinder $\sqrt[3]{\frac{l\,W}{4\,S}} = b$ *and* d.

pported at Both Ends. Loaded at any Other Point than in Middle.

s, Beams, etc. $\frac{m\,n\,W}{l\,b\,d^2} = S$; $\frac{S\,l\,b\,d^2}{m\,n} = W$; $\frac{m\,n\,W}{S\,b\,d^2} = l$; $\frac{m\,n\,W}{S\,l\,d^2} = b$;

$\sqrt{\frac{m\,n\,W}{S\,l\,b}} = d$; and Cylinder $\sqrt[3]{\frac{m\,n\,W}{S\,l}} = b$ *and* d.

Square Beams, etc., for b and d put $\sqrt[3]{\frac{l\,W}{S}} = \sqrt{\frac{l\,W}{S\,b}} = d$. In Cylinders, for ut d^3 as above.

en weight is uniformly distributed, same formulas v... ., W representing only half required or given weight.

presenting stress in a Bar, Beam, or Cylinder, one foot ... inch side, or in diameter; and W weight, in lbs.; b breadt... ; h, m distance of weight from one end, and n from the ot...

Brick-work.

brick arch, having a rise of 2 feet, and a span of 1 a width, with a depth at its crown of 4 ins., bore 358 ntre.

Coefficient or Factor of Safety.

Coefficient or factor of safety of different materials must be taken in view of importance of structure, or instrument, probable or required period of duration of it, and if it is to bear a quiescent, vibratory, gradual, or percussive stress, and to meet these varied conditions, it will range from .125 to .3 of the maximum or ultimate strength here given or ascertained.

To Compute Transverse Strength of a Rectangular Bar or Beam.

When a Bar or Beam is Fixed at One End, and Loaded at the Other. RULE.—Multiply *Coefficient* of material in preceding Tables, or, as may be ascertained, by breadth and square of depth in ins., and divide product by length in feet.

NOTE.—When a beam, etc., is loaded uniformly throughout its length, result must be doubled.

EXAMPLE.—What weight will a cast-iron bar, 2 ins. square and projecting 30 ins. in length, bear without permanent injury?

Assume strength of material at 660, and its elasticity at one fifth or .2 of its strength.

$$\text{Then } \frac{660 \times .2 \times 2 \times 2^2}{2.5} = \frac{1056}{2.5} = 422.4 \textit{ lbs.}$$

If Dimensions of a Beam or Bar are Required to Support a Given Weight at its End. RULE.—Divide product of weight and length in feet by *Coefficient* of material, and quotient will give product of breadth and square of depth.

EXAMPLE.—What is the depth of a wrought-iron beam, 2 ins. broad, necessary to support 576 lbs. suspended at 30 ins. from fixed end?

Assume strength of iron at 150.

$$\text{Then } \frac{2.5 \times 576}{150} = 9.6, \text{ and } \sqrt{\frac{9.6}{2}} = 2.19 \textit{ ins. depth.}$$

When a Beam or Bar is Fixed at Both Ends, and Loaded in the Middle. RULE.—Multiply *Coefficient* of material by 6 times breadth and square of depth in ins., and divide product by length in feet.

NOTE.—When beam is loaded uniformly throughout its length, result must be doubled.

EXAMPLE.—What weight will a bar of cast iron, 2 ins. square and 5 feet in length, support in middle, without permanent injury?

Assume strength of material as in a previous case at .2 of 660.

$$\text{Then } \frac{660 \times .2 \times 2 \times 6 \times 2^2}{5} = \frac{6336}{5} = 1267.2 \textit{ lbs.}$$

If Dimensions of a Beam or Bar are Required to Support a Given Weight in Middle, between Fixed Ends. RULE.—Divide product of weight and length in feet by 6 times *Coefficient* of material, and quotient will give product of breadth and square of depth.

EXAMPLE.—What dimensions will a square cast-iron bar, 5 feet in length, require to support without permanent injury a stress of 2160 lbs.?

Assume strength of material at .2 of 660 or 132, as preceding.

$$\frac{2160 \times 5}{\cdot 2 \times 6} = \frac{10\,800}{792} = 13.64, \textit{ which, divided by 2 for assumed breadth} = 6.82,$$
$= 2.61$ *ins. depth.*

...adth or Depth is Required. RULE.—Divide product obtained ...ules by square of depth, and quotient is breadth; or by ...oot of quotient is depth.

... product, and depth is 8; then $128 \div 8^2 = 2$, breadth ... $= 8$, depth.

ı Weight is not in Middle between Ends. RULE.—Multiply *Coefficient* ɜrial by 3 times length in feet, and breadth and square of depth in d divide product by twice product of distances of weight, or stress ther end.

PLE.—What weight will a cast-iron bar, fixed at both ends, 2 ins. square and length, bear without permanent injury, 2 feet from one end?

ıe strength of material at .2 of 660 or 132, as preceding.

$$\text{Then } \frac{132 \times 3 \times 5 \times 2 \times 2^2}{2 \times (2 \times 3)} = \frac{15\,840}{12} = 1320 \text{ } lbs.$$

ı a Beam or Bar is Supported at Both Ends, and Loaded in Middle. –Multiply *Coefficient* of material by 4 times breadth and square of ı ins., and divide product by length in feet.

—When beam is loaded uniformly throughout its length, result must be

ᑭLE.—What weight will a cast-iron bar, 5 feet between the supports, and 2 ıre, bear in middle, without permanent injury?

ıe strength of iron at 132, as preceding.

$$\text{Then } 132 \times 2 \times 4 \times 2^2 = 4224 \div 5 = 844.8 \text{ } lbs.$$

imensions are Required to Support a Given Weight. RULE.—Divide ; of weight and length in feet by 4 times *Coefficient* of material, and t will give product of breadth, and square of depth.

ı Weight is not in Middle between Supports. RULE.—Multiply *Coef-* ɔf material by length in feet, and breadth and square of depth in ins., 'ide product by product of distances of weight, or stress from either

ᑭLE.—What weight will a cast-iron bar, 2 ins. square and 5 feet in length, without permanent injury, at a distance of 2 feet from one end, or support?

ıe strength of iron at 132, as preceding.

$$\text{Then } \frac{132 \times 5 \times 2 \times 2^2}{2 \times (5-2)} = \frac{5280}{6} = 880 \text{ } lbs.$$

ompute Pressure upon Ends or upon Supports.

: 1.—Divide product of weight and its distance from nearest end or , by whole length, and quotient will give pressure upon end or sup- 'thest from weight.

)ivide product of weight and its distance from farthest end, or sup- ' whole length, and quotient will give pressure upon end or support weight.

ᑭLE.—What is pressure upon supports in case of preceding example?

$\frac{2}{-} = 352$ *lbs. upon support farthest from the weight;* $\frac{880 \times 3}{5} = 528$ *lbs. upon nearest to weight.*

ı a Bar or Beam, Fixed or Supported at Both Ɩ ˜wo ! at Unequal Distances from Ends.

$$\frac{W}{L} + \frac{l\,w}{L} = \textit{pressure at } w \textit{ end}, \text{ and } \frac{n\,w}{L} + \frac{l'\,W}{L} = \textit{pressure}$$

! n representing distances of greatest and least weights fr nd w greatest and least weights, L whole length, l distance f st end, and l′ distance of greatest weight from farthest end.

ʀATION.—A beam 10 feet in length, having both ends fixed : ;hts—viz., one of 1000 lbs., at 4 feet from one of its ends, an , at 4 feet from the other end; what is pressure upon each en

$$\frac{\text{∞}}{} + \frac{6 \times 1000}{10} = 1400 \text{ } lbs. \text{ } at \text{ } w; \quad \frac{4 \times 1000}{10} + \frac{6 \times 2000}{10} = 1600 \text{ } lb.$$

When Plane of Bar or Beam Projects Obliquely Upward or Downward.

When Fixed at One End and Loaded at the Other. RULE.—Multiply *Co-efficient* of material by breadth and square of depth in ins., and divide product by product of length in feet and *cosine* of angle of elevation or depression.

NOTE.—When beam is loaded uniformly along its length, result must be doubled.

EXAMPLE.—What is weight an ash beam, 5 feet in length, 3 ins. square, and projecting upward at an angle of 7° 15′, will bear without permanent injury?

Assume breaking weight of ash at 160, and its elasticity at .25 of its strength; *cosine* of 7° 15′ = .992.

$$\text{Then } \frac{160 \times .25 \times 3 \times 3^2}{5 \times .992} = \frac{1080}{4.96} = 217.74 \textit{ lbs.}$$

To Compute Transverse Strength of an Equilateral Triangle or T Beam.

RULE.—Proceed as for a rectangular beam, taking following proportions of *Coefficient* of material:

Fixed at One or Both Ends.	Equilateral triangle, edge up	$b \times d^2 \times .2$
	Equilateral triangle, edge down	$b \times d^2 \times .34$
	T beam, flange up	$b \times d^2 \times .42$
Supported at Both Ends.	Equilateral triangle, edge up	$b \times d^2 \times .34$
	Equilateral triangle, edge down	$b \times d^2 \times .2$
	T beam, flange up	$b \times d^2 \times .42$

To Compute Transverse Strength of a Solid Cylinder.

RULE.—Proceed as for a rectangular beam, and take .6 of *Coefficient* of product.

A mean of 18 results with cold blast gun-metal, gave a coefficient for 740 lbs.

When Fixed at One End, and Loaded at the Other. RULE.—Multiply weight to be supported in lbs. by length of cylinder in feet, divide product by .6 of *Coefficient* of material, and cube root of quotient will give diameter.

NOTE.—When cylinder is loaded uniformly throughout its length, cube root of half quotient will give diameter

EXAMPLE.—What should be diameter of a cast-iron cylindrical beam of gun-metal, 8 ins. in length, to break at 15 000 lbs.?

$$\sqrt[3]{\frac{15\,000 \times \overline{8 \div 12}}{.6 \times 740}} = \sqrt[3]{\frac{10\,000}{444}} = 2.82 \textit{ ins.}$$

When Fixed at Both Ends, and Loaded in Middle. RULE.—Multiply weight to be supported in lbs. by length of cylinder between supports in feet; divide product by .6 of *Coefficient* of material, and cube root of one sixth of quotient will give diameter.

NOTE.—When cylinder is loaded uniformly along its length, cube root of half the quotient will give diameter.

EXAMPLE.—What is the diameter of a cast-iron cylinder of gun-metal, 2 feet between supports, that will break at 35 964 lbs.?

$$\frac{35\,964 \times 2}{.6 \times 740} = 162, \text{ and } \sqrt[3]{\frac{162}{6}} = 3 \textit{ ins.}$$

Mean results of cylinder and square bars gave 444 and 740 lbs. Hence, strength of a cylinder compared to a square is as 444 to 740 or .6 to 1.

$$\text{Then } \frac{4 \times 3^3 \times 444}{1} = 47\,952 \textit{ lbs.}$$

To Compute Diameter of a Solid Cylinder to Support a given Weight.

When Supported at Both Ends, and Loaded in Middle. RULE.—Multiply weight to be supported in lbs. by length of cylinder between supports in feet; divide product by .6 of Coefficient of material, and cube root of one fourth of quotient will give diameter.

OTE.—When cylinder is loaded uniformly along its length, cube root of half the tient will give diameter.

XAMPLE.—What is diameter of a cast-iron gun-metal cylinder, 1 foot between its ports, that will break at 48 000 lbs.?

$$\frac{48\,000 \times 1}{.6 \times 740} = 108, \text{ and } \sqrt[3]{\frac{108}{4}} = 3 \textit{ ins.}$$

Rectangular. (*D. K. Clark.*)

(1) *Loaded at Middle.* $\frac{8\,b\,d^2}{l} = W$. (2) *Loaded at One End.* $\frac{2\,b\,d^2}{l} = W$.

Cylindrical.

) *Loaded at Middle.* $\frac{5.5\,b\,d^2}{l} = W$. (4) *Loaded at One End.* $\frac{1.375\,b\,d^2}{l} = W$.

V *representing ultimate stress in tons.*

Above *Coefficients* are for iron of a tensile strength of 7 tons per sq. inch.

	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
Ience, for 8 tons put	9.2	2.3	6.3	1.6	For 12 tons put	13.8	3.4	9.4	2.4
9 "	10.4	2.6	7.1	1.8	13 "	14.5	3.6	10.2	2.6
10 "	11.5	2.9	7.9	2	14 "	16	4	11	2.8
11 "	12.7	3.2	8.6	2.2	15 "	17.2	4.3	11.8	3

› Compute Destructive Weight, or Loads that may be borne by Wrought-iron Rolled Beams and Girders, or Riveted Tubes of various Figures and Sections.

Supported at Both Ends. Load applied in Middle.

Vhen Section of Beam or Girder is that of any of the Figures in follow- Table. RULE.—Divide product of area of section, depth, and *Coefficient* girder, etc., from following Table, by length between supports in feet, quotient will give destructive weight in lbs.

OTE.—The *Coefficients* given are based upon experiments with English iron.

Solid Beams.

LLUSTRATION.—What load will destroy a wrought-iron grooved beam of following ensions, 10 feet in length between supports, and loaded in its middle?

Flanges, 5.7 × .6 inch; Web, .6 inch; Depth, 11.75 ins.; Area, 13.34 sq. ins.

ssume *Coefficient* 4638 as for like case (11) in following table, page 806.

$$\frac{13.34 \times 11.75 \times 4638}{10} = \frac{726\,983}{10} = 72\,698.3 \textit{ lbs.}$$

Ultimate stress for such a beam by experiment was estimated at 97 997 lbs.

Formulas of Various Authors give following Results:

). K. CLARK. $\frac{d\,(4\,a + \overline{1.1555\,a'})}{.6\,l} = W$. *a representing area of section of lower nge, a' area of section of web, less one flange, d depth of beam, less average depth ne flange, all in ins., l length in feet, and* W *ultimate destructive weight in tons.*

his formula is based upon the assumption that the beam ha   ...nort.

$$\frac{\overline{1.75 - .6}\,(4 \times \overline{5.7 \times .6} + 1.155 \times \overline{11.75 - .6} \times .6)}{.6 \times 10} = \frac{238.69}{6} = \quad 324$$

9 107 *lbs.*

OLESWORTH. $\frac{4\,C\,b\,d^2}{l} = W$. $C = 7616$ *lbs., and for* $b\,d^2$ p

d d representing exterior and b' and d' interior dimensions, a

$$5.7 \times 11.75^2 - [5.7 - .6 \times \overline{11.75 - (.64 \times 2^2)}] = 786.6 - 558.$$

$$\text{Then } \frac{4 \times 7616 \times 227.7}{10 \times 12} = \frac{6\,936\,652}{120} = 57\,805.4 \textit{ lbs.}$$

Fairbairn's formula would give a result less than half of the first, a s alike to that of Molesworth.

WROUGHT IRON.

Transverse Strength of Wrought-iron Rolled Beams and Girders. (*Barlow, Fairbairn, Hughes, Kirkaldy, etc.*)

Reduced to Uniform Measure of One Foot in Length.

Supported at Both Ends; Stress or Weight applied in Middle.

Section.	Flanges.	Web.	Depth (d).	Distance.		Area (A).	Destructive Weight. For Distance.	Destructive Weight. Length of One Foot (l).	$\frac{l\,W}{A\,d}=C$
	Ins.	Ins.	Ins.	Feet.	Ins.	Sq. Ins.	Lbs.	Lbs. (W)	
	—	1	1	1		1	2 500	2 500	2500
	—	2	2	2	9	4	6 600	18 150	2266
	—	1.5	3	2	9	4.5	10 080	27 720	2053
"	—	1	3	3		3	7 050	21 150	2350
	—	1	1	5		.78	474	2 370	2370
	3.5 × .6	.8	3.5	2	7	5.65	20 160	52 480	2654
	2.5 × 1 4 × .38	.325	7	2	9	5.9	44 000	121 000	2930
	2.6 × 1.25	.85	5	4	6	7.44	19 000	85 500	2298
"	3 × .49	.5	7.07	10		5.87	24 200	242 000	5830
	4.6 × .8	.5	9.85	20		11.5	38 080	761 600	6724
	5.7 × .64	.6	11.75	10		13.34	72 688	726 880	4638
	2.85 × .38	.31	2.5	4		1.75	3 150	12 600	2880
	7 × .5 4 × .5	.38	16.5	22	6	18.9	49 280	1 108 800	3556
	4.5 × .375 2 × 2 × .3125	.38	14.25	16	5	10.5	47 000	775 500	5183
	4.5 × 28 4.5 × 3	.25	7	7		6.35	24 380	170 660	3840
	3.9 3.9	.13	6	7	6	2.62	9 976	74 820	4766
	15.5 15.5	.53	24	30		41.4	128 885	3 866 550	3596
"	24 24	.75 .75	35.75	45		87.38	257 080	11 568 600	3703
	—	.131	12.4 12.138	10		5.05	17 885	178 850	2856
	—	.143	15 9.75	10		5.56	26 250	262 500	3147
STEEL.	—	.75	5.2	5		7.72	102 480	512 400	12760

…sults are very conclusive of the correctness of above formula, as …n cases given, and they are deduced from beams and girders …t to 45 feet in length; hence, when length of a beam or girder …sections given is less, relative breaking weight may be in… …uence of increased stability of beam or girder.

…ts on Tubes and Tubular Girders, etc., see *Rep. of Comm's on* …ondon, 1849.

…l iron assumed at 45 000 lbs. per sq. inch.

ed Wrought-iron Beams and Channel Bars.

With Safe Load Uniformly Distributed for Length of One Foot.

New Jersey Steel and Iron Co., Trenton, N. J.

(*Beams Supported Sidewise.*)

t.	Designation.	Width. Web.	Width. Flange.	Area. Web.	Area. Flange.	Area. Total.	Weight per Foot.	Load.
	I BEAMS.	Inch.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Lbs.	Lbs.
ins.	Extra Light	.1875	2	.75	1.02	1.77	6	18 000
"	Light	.25	2.75	1	1.91	2.91	10	30 100
"	Heavy	.3125	3	1.25	2.41	3.66	12.3	36 800
"	Light	.25	2.75	1.2	1.79	2.99	10	38 700
"	Heavy	.3125	3	1.56	2.34	3.9	13.3	49 100
"	Light	.25	3	1.5	2.51	4.01	13.3	62 600
"	Heavy	.3	3.5	1.8	3.11	4.91	16.7	76 800
"	90 lbs.	.5	5	3	5.7	8.7	30	132 000
"	120 "	.625	5.25	3.75	8.09	11.84	40	172 000
"	55 "	.3	3.75	2.1	3.4	5.5	18.3	101 000
"	Light	.3	4	2.4	3.97	6.37	21.7	135 000
"	Heavy	.375	4.5	2.96	5.07	8.03	26.7	168 000
"	Light	.3	4	2.7	4.3	7	23.3	167 000
"	Heavy	.375	4.5	3.38	5.12	8.5	28.3	199 000
"	Extra Heavy	.57	4.5	5.13	7.2	12.33	41.7	268 000
"	Extra Light	.3125	4.5	3.28	5.62	8.9	30	250 000
"	Light	.375	4.5	3.94	6.5	10.44	35	286 000
"	Heavy	.47	5	4.93	8.43	13.36	45	360 000
"	Extra Light	.32	5.25	3.84	5.62	9.46	32	306 000
"	Light	.39	5.5	4.68	7.05	11.73	40	375 000
"	Light	.47	4.8	5.75	6.58	12.33	41.7	377 000
"	Heavy	.6	5.5	7.39	9.38	16.77	56.66	511 000
"	Extra Light	.42	5	6.35	6.01	12.36	41.7	460 000
"	Light	.5	5	7.59	7.45	15.04	50	551 000
"	Heavy	.6	5.75	9.07	10.95	20.02	66.66	748 000
"	Light	.5	6	10.5	9.97	19.97	66.66	990 000
"	Heavy	.6875	6.75	13.75	13.45	27.2	90.66	1 320 000
	DECK BEAMS.							
"	—	.3125	4.5	2.17	3.18	5.35	18.3	63 500
"	—	.375	4.5	3.04	3.25	6.29	21.7	91 800
	CHANNELS.							
"	Extra Light	.2	1.5	.6	.85	1.45	5	10 500
"	" "	.2	1.5	.8	.85	1.65	5.5	15 700
"	" "	.2	1.625	1	.92	1.92	6.3	22 800
"	" "	.18	1.875	1.08	1.17	2.25	7.5	33 680
"	Light	.28	2.25	1.68	1.52	3.2	11	45 700
"	Heavy	.4	2.5	2.4	1.92	4.32	15	58 300
"	Extra Light	.2	2	1.4	1.14	2.54	8.5	39 500
"	Light	.25	2.5	1.75	1.85	3.6	12	62 000
"	Extra Light	.2	2.2	1.6	1.7	3.3	11	65 800
"	Light.	.26	2.5	2.08	2.4	4.48	15	88 950
"	"	.33	2.5	2.97	2.11	5.08	16.7	104 000
"	Heavy	.43	3.125	3.87	3.15	7.02	23.3	146 000
"	Extra Light	.3125	2.5	—	—	4.8	16	102 000
"	Light	.375	2.75	3.94	2.06	6	20	134 750
"	"	.33	3	4.04	2.96	7	23.3	200 100
"	Heavy	.68	4	8.33	5.77	14.1	46.7	381 000
"	Light	.5	4	7.5	4.5	12		
"	Heavy	.75	4.75	11.25	7.6	18.[illegible]		

s given in table are such as will effect a maximum str
o lbs. per sq. inch. For permanent stress, absolutely fr
· strain would be allowable, and, contrariwise, if the st
e load, the loads here given should be reduced.

l

A difference of 25 per cent. in either direction should be made, according to character of load to be supported or stress to be borne.

Elastic Transverse Strength of Wrought-iron Bars is about 45 per cent. of their transverse strength, of Solid rolled beams, 50 per cent.; and of double-headed rails, 46 per cent. of their transverse strength; of Fagersta Steel, 56 per cent. of its transverse strength; of double-headed Steel rails, 47 per cent.; of Bessemer Steel, 37.5 to 48 per cent.; and of Steel flanged, 68 per cent.

Transverse strength of Solid Cast-iron Beams or Girders is about 50 per cent. of ultimate strength.

NOTE.—Actual breaking weight of a 10.5 ins. beam of New Jersey Steel and Iron Co., weight 35 lbs. per foot, for a length of span of 20 feet, is 60 000 lbs.

Rolled Steel Beams.

With Safe Load Uniformly Distributed for Length of One Foot.

The New Jersey Steel and Iron Co., Trenton, N. J.

(Beams Supported Sidewise.)

Depth.	Designation.	Width. Web.	Width. Flange.	Area. Web.	Area. Flange.	Total Area. Min.	Total Area. Max.	Weight per Foot. Min.	Weight per Foot. Max.	Load.
Ins.	I BEAMS.	Ins.	Ins.	Sq. ins.	Sq. ins.	Sq. ins.	Sq. ins.	Lbs.	Lbs.	Lbs.
1.25	—	.125	1.5	—	—	.515	.515	1.75	1.75	2 300
4	Light	.2	2.62	—	—	2.21	3.15	7.5	10.7	31 400
4	Heavy	.24	2.75	—	—	2.94	3.91	10	13.3	41 200
5	Light	.22	3	—	—	2.94	4.12	10	14	52 900
5	Heavy	.26	3.13	—	—	3.81	5.09	13	17.3	67 000
6	Light	.25	3	—	—	3.91	5.39	13.3	18.3	83 000
6	Heavy	.3	3.5	—	—	4.89	6.35	16.6	21.6	104 000
7	Light	.23	4	—	—	4.56	6.35	15.5	21.6	118 000
7	Heavy	.27	4.25	—	—	5.88	7.82	20	26.6	151 000
8	Light	.25	4.25	—	—	5.29	7.35	18	25	154 000
8	Heavy	.27	4.5	—	—	6.47	8.33	22	28.3	192 000
9	Light	.27	4.5	—	—	6.17	8.33	21	28.3	200 000
9	Heavy	.31	4.75	—	—	7.94	10.29	27	35	262 000
10	Light	.32	4.75	—	—	7.15	9.89	25.3	33.3	264 000
10	Heavy	.37	5	—	—	9.71	12.26	33	41.7	344 000
10	Extra Heavy	.45	5.25	—	—	13.24	15.69	45	53.33	401 000
12	Light	.32	5.25	—	—	9.41	12.26	32	41.7	407 000
12	Heavy	.39	5.5	—	—	11.74	14.7	40	50	500 000
15	Light	.4	5.5	—	—	12.59	15.69	41	53.33	603 000
15	Heavy	.45	5.75	—	—	14.71	18.63	50	63.33	753 000

Loads given in table are such as will effect a maximum strain upon the metal of 16 000 lbs. per sq. inch, and are for the Minimum area.

Steel beams have greater estimated strength than iron, but their stiffness is not materially greater.

Operation of Tables.

To Compute Depth of a Beam to Support a Uniformly Distributed Load.

RULE.—Multiply load in lbs. by length of span in feet, and take from table the beam, load of which is nearest and in excess of product obtained.

EXAMPLE.—What should be depth of an iron beam to sustain with safety a uniformly distributed load of 30 000 lbs., over a span of 15 feet?

30 000 × 15 = 450 000, which is load for a heavy beam 12.25 ins. in depth.

Weight of beam should be added to load.

Inversely.—If the load is required, divide load in table by span of beam in feet, subtract weight of beam.

Compute Deflection of Like Beams.

ide square of span in feet by 70 times depth of beam in ins.

'sume beam as preceding.

$$\frac{15^2}{70 \times 12.25} = \frac{225}{857.5} = .262 \textit{ ins.}$$

mparative Strength and Deflection of Cast-iron Flanged Beams.

Description of Beam.	Comp. Strength.	Description of Beam.	Comp. Strength.
of equal flanges	.58	Beam with flanges as 1 to 4.5...	.78
with only bottom flange..	.72	" with flanges as 1 to 5.5...	.82
with flanges as 1 to 2....	.63	" with flanges as 1 to 6.....	1
with flanges as 1 to 4....	.73	" with flanges as 1 to 6.73..	.92

ıensions and Proportions of Wrought-iron Flanged Beams. (*D. K. Clark.*)

th.	Breadth of Flanges.	Thickness. Web.	Thickness. Flanges.	Weight per Lineal Foot.	Ultimate Strength. Loaded in Middle.	Safe Stress Uniformly Distributed.
s.	Ins.	Inch.	Inch.	Lbs.	Lbs.	Lbs.
	2	.1875	.2187	5.5	2 800	910
	3	.25	.3125	10	5 600	1 860
:25	1.625	.1875	.2187	5.5	2 490	830
	2	.25	.3125	8	5 490	1 830
	3	.25	.375	12	8 510	2 830
'5	2	.25	.3125	8	6 940	2 310
	3	.3125	.4375	13	13 440	4 480
	4.5	.375	.5	23	19 270	6 420
;	2	.375	.4375	10	11 880	3 960
	5	.4375	.5625	30	23 830	7 940
:5	2	.3125	.4375	11	13 440	4 440
:5	2.25	.3125	.375	18	13 000	4 330
:5	3.25	.3125	.4062	12.5	17 470	5 820
	2.25	.281	.375	14	14 790	4 930
	2.25	.3125	.4375	14	17 020	5 070
	3.625	.3125	.4375	19	23 300	7 760
	3.625	.3125	.5	19	25 980	8 660
	2.375	.3125	.4375	15	20 830	6 940
	2.5	.375	.375	15	21 280	7 090
	4	.375	.5	21	4 500	11 500
	5	.375	.5625	29	44 800	14 930
	5.125	.4375	.5625	29	47 040	15 680
5	3.75	.4375	.5	24	41 560	13 850
	4.5	.375	.6875	30	59 360	19 750
	4.5	.4375	.5625	32	56 000	18 660
	4.75	.4375	.5625	32	58 240	19 410
	4.75	.75	.625	36	76 160	25 390
	5	.5625	.8175	42	100 800	33 600
	6	.5625	.9375	56	136 640	45 530
	5.5	.5625	.875	60	150 020	50 000
	6	.5625	.8175	60	152 260	50 750
	5.625	.75	.8175	62	188 160	62 720

ought-iron Rectangular Girders or Tubes. (*Riv'd.*)

Supported at Both Ends. Loaded in Middle.

$\frac{C}{} = W$. A *representing area of section in sq. ins., d depth in ins., l length be-supports in feet, and* W *destructive weight in lbs.*

ıstration.—What is the destructive weight of a rectangular girder, 35.75 ins. th by 24 in breadth, metal .75 inch thick, and length between supports 4- ıme C or coefficient = 3700, as per case (18) in preceding table, pε ·ea = 87.375 ins.

$$\text{Then } \frac{87.375 \times 35.75 \times 3700}{45} = \frac{11\,557\,528}{45} = 256\,833.9 \; lbs.$$

experiment it was 257 080 *lbs.* By Inversion $\frac{W\,l}{C\,d} = A$, and $\frac{l\,W}{A\,C} = d$.

ıgkinson's formula would give a result of 259 373 lbs., and Moleswo. 7 lbs.

Unequally Loaded Beams, etc.

[illegible] = [illegible]. l representing length between supports, and m and n distances from [illegible] of support, all in like denomination, and W [illegible] destructive and safe weight [illegible] in like denomination.

To Compute Destructive Weight and Area of Bottom Plate.

[illegible] = W, [illegible] = [illegible], and [illegible] = A. A representing area of plate in sq. [illegible], d and l depth and length, m and n distances of load at other points than [illegible] middle, all in feet, and W weight in lbs.

Note.—Sufficient metal should be provided in sides to resist transverse [illegible] shearing stress, and in upper flange to resist crushing.

Illustration.—What area of wrought iron is necessary in bottom plate of a [illegible] tubular girder, [illegible] feet in depth, supported at both ends, and loaded in middle [illegible] lbs.?

[illegible] ascertained by experiment for destructive stress, [illegible] lbs., and area [illegible]

[illegible] = [illegible] sq. ins.

Wrought-iron Cylindrical Beams or Tubes.

[illegible] = W. Illustration.—What is destructive weight of a cylindrical tube [illegible] ins. in diameter, [illegible] inch in thickness, and [illegible] feet between its supports?

Area of metal = [illegible] sq. ins., and C = [illegible], as in the [illegible] case of table, page [illegible]

Then [illegible] = [illegible] lbs.

D. K. Clark. [illegible] = W. d representing diameter, t thickness of metal, [illegible] length, all in ins., S tensile strength of metal per sq. inch, and W weight, both in lbs.

S = [illegible] lbs. [illegible] = [illegible] = [illegible] lbs.

[illegible]'s formula gives a result of [illegible] lbs.

Wrought-iron Elliptical Beams or Tubes.

[illegible] = W. Illustration.—Assume diameter of tube 9.75 and 15 ins., and [illegible] inch in thickness, and distance between supports 10 feet.

A = 5.56 sq. ins. C = [illegible], as per case [illegible] in preceding table, page [illegible]

Then $\frac{5.56 \times 15 \times [illegible]}{10} = \frac{[illegible]}{10} = 26\,245.9$ lbs.

D. K. Clark. $\frac{1.57\,(b^2 + d^2)\,t\,S}{l} = W$. b and d representing conjugate and transverse diameter, l length between supports, t thickness of metal, all in ins., S tensile strength of metal per sq. inch, and W destructive weight, both in lbs.

$S = 44\,000$ lbs. $\frac{1.57\,(9.75^2 + 15^2) \times .243 \times 44\,000}{10 \times 12} = \frac{3\,161\,840}{120} = [illegible]$ lbs.

Note.—B. Baker, in his work on Strength of Beams, etc., London, [illegible] shows that ordinary method of computing transverse strength of a hollow [illegible] difference of diameter alone is erroneous, in consequence of loss of resistance [illegible] flexure in a hollow beam.

Girders and Beams of Unsymmetrical Section.

$\frac{4\,S\,d}{l} = W$. S representing tensile resistance of metal, and W destructive weight, both in lbs., d distance between centres of compression and extension, or crushing and tensile resistances, in ins., and l length between supports, in feet.

Note.—To ascertain d, see Rule, page 819.

ILLUSTRATION.—Dimensions of a rolled wrought-iron girder, 11 feet in length be- ɔen its supports, is as follows:

ɔ flange................ 2.5 × 1 inch.	Bottom flange............ 4 × .38 inch.
ɔb .... .325 "	Depth .... 7 ins.

What is its destructive weight?

$d = 5.22$ ins. S assumed at 45000 lbs. Then $\frac{4 \times 45000 \times 5.22}{11 \times 12} = 7118.18$ *lbs.*

Strength of Riveted Beams or Girders, compared with Solid, is less, and deflec- ɔn is greater

Wrought-iron Inclined Beams, etc.

$\frac{L\,W}{l} = w$. *L and l representing lengths or inclination, and horizontal line, in like nominations, and W and w destructive and safe weights on horizontal line and in- lination, also in like denominations.*

Plate Girders.

$\frac{A\,d\,C}{l} = W$. *A representing section in sq. ins., d depth in ins., and l length between supports in feet.*

ILLUSTRATION.—What load will destroy a wrought-iron plate girder or beam of lowing dimensions, 10 feet in length between its supports?

ɔ flange.............. 4.5 × .375 inch.	Width of web............... .375 inch.
ttom flange.......... 4.5 × .375 "	Depth of web............... 13.5 ins.
gle pieces............ 2 × .3125 "	Depth of beam.............. 14.25 "

Area of Section = 13 *sq. ins.*

Assume coefficient of 5180 as per case (14) in preceding Table, page 806.

$$\text{Then } \frac{13 \times 14.25 \times 5180}{10} = \frac{959595}{10} = 95959.5 \textit{ lbs.}$$

MOLESWORTH. $\frac{L\,l}{8\,d} = S$. L *representing load equally distributed, and S stress on ɔtre, both in tons, and d effective depth of girder in feet.*

By actual experiment L = 48 tons for 16.5 feet between supports; hence, :16 5 :: 48 : 79.2 *tons* = 39.6 when supported in middle, and 14.25 *ins.* = 1.1875 *feet.*

$$\text{Then } \frac{39.6 \times 10}{8 \times 1.1875} = \frac{396}{9.5} = 41.68, \text{ which} \times 2240 = 93363.2 \textit{ lbs.}$$

D. K. CLARK. $\frac{d\,(4\,a + 1.155\,a')}{.6\,l} = W$. *d representing depth of girder or beam ' depth of lower flange in ins., a and a' areas of sections of bottom flange and of ɔ, at its reputed depth, both in sq. ins., and l length between supports in feet.*

$$d = 14.25 - .375 = 13.875 \textit{ ins.} \quad a = 3, \text{ and } a' = 5 \textit{ sq. ins.}$$

$$\text{Then } \frac{13.875\,(4 \times 3 + \overline{1.155 \times 5})}{.6 \times 10} = \frac{246.63}{6} = 41.105, \text{ which} \times 2240 = 92075.2 \textit{ lbs.}$$

Mr Clark assumes, however, that for girders of like construction the destructive ess should be taken at two thirds of that deduced by the formula.

Girders or Beams without Upper and Lower Flanges.

ILLUSTRATION. — Assume angles 2.125 × .28 above, 2.125 × .3 below, web .25, depth 7 ins., and length between supports 7 feet.

Area of section = 6.35 *sq. ins.*, and C = 3840, as per case (15) in preceding Table, page 806.

$$\text{Then } \frac{6.35 \times 7 \times 3840}{7} = \frac{170688}{7} = 24384 \textit{ lbs.}$$

Approximate. $\frac{\frac{a}{2} + .25\,a' \times 5\,d}{l} = W$. *a representing area of sections of nd lower angles, a' area of section of web for total depth, both in sq. ins., d d irder in ins., and W load or stress in lbs.*

$a = 4.6$ *sq. ins.*, and $a' = 7 \times .25 = 1.75$ *sq. ins.*

$$\text{Then } \frac{\dfrac{4.6}{2} + \dfrac{1.75}{4} \times 5 \times 7}{7} = \frac{95.81}{7} = 13.687, \text{ which} \times 2240 = 30658.8 \textit{ lbs.}$$

IRON AND STEEL RAILS.

Symmetrical Section.

To Compute Transverse Strength. (*D. K. Clark.*)

$$\frac{S\left(4\,a\,\dfrac{d'^2}{d} + \overline{1.155\,t\,d^2}\right)}{l} = W, \text{ and } \frac{W\,l}{\left(4\,a\,\dfrac{d'^2}{d} + 1.155\,t\,d^2\right)} = S.$$

S *representing ten-sile strength in lbs. or tons per sq. inch, a area of one head or flange exclusive of central portion composing web, in sq. ins., d′ depth or distance between centres of heads, d depth of rail, t thickness of web, l distance between supports, all in ins., and W weight in lbs. or tons, alike to* S.

ILLUSTRATION 1.—What is destructive weight of a wrought-iron double-headed rail, 5.4 ins. deep, having a web of .8 ins., an area of head of 1.9 sq. ins., distance between centres of its heads 4.2 ins., and between its supports 5 feet?

S assumed at 50 000 *lbs.*

$$\text{Then } \frac{50\,000\left(4 \times 1.9 \times \dfrac{4.2^2}{5.4} + \overline{1.155 \times .8 \times 5.4^2}\right)}{5 \times 12} = \frac{50\,000 \times (24.82 + 26.94)}{60} =$$

43 125 *lbs.*

2.—What is destructive weight of a Bessemer steel double-headed rail, 5.4 ins. deep, having a web of .75 inch, an area of head of 2 sq. ins., and distance between heads 4.2 ins.?

S assumed at 80 000 *lbs.*

$$\text{Then } \frac{80\,000\left(4 \times 2 \times \dfrac{4.2^2}{5.4} + \overline{1.155 \times .75 \times 5.4^2}\right)}{5 \times 12} = \frac{80\,000 \times 51.39}{60} = 68\,520 \textit{ lbs.}$$

NOTE.—Transverse strength of Bessemer Rails increases very generally, in direct proportion with the proportion of Carbon in it.

Unsymmetrical Section.

$\frac{6.92\,S\,d''\,A}{l\,h} = W.$ *d″ representing vertical distance between centres of tension and compression, h height of neutral axis above base of section, and l length between supports, all in ins., and A sum of products, obtained by multiplying areas of strips of reduced section under tensile stress, by their mean distances, respectively, that is, the distances of their centres of gravity, from the neutral axis, in ins.*

Bowstring Girder.

To Compute Diameter of a Wrought-iron Tie-rod of an Arched or Bowstring Girder of Cast Iron.

$\sqrt{\frac{W\,l}{4500 \times h}} = d.$ W *representing weight distributed over beam in lbs., l length between piers or supports in feet, and h height between centre of area of section of girder and centre of rod in ins.*

ILLUSTRATION.—Required diameter of tie-rod for an arched girder, 25 feet between its piers, and 30 ins. between centres of its area and of rod, to safely support a uniformly distributed load of 25 000 lbs.?

$$\sqrt{\frac{25\,000 \times 25}{4500 \times 30}} = \sqrt{\frac{625\,000}{135\,000}} = \sqrt{4.62} = 2.15 \textit{ ins.}$$

If two rods are used Then $\sqrt{\frac{4.62}{2}} = 1.52$ ins. = diameter of each rod.

CAST IRON.

Transverse Strength of Girders and Beams.

ıced from Experiments of Barlow, Hodgkinson, Hughes, Bramah, Cubitt, Tredgold, and others.)

Reduced to a Uniform Measure of One Foot in Length.

Supported at Both Ends. Stress or Weight applied in Middle.

·.	Flanges.	Web.	Depth.	Distance.	Area.	Destructive Weight. For Distance.	Destructive Weight. Length of One Foot.	$\frac{l\,W}{A\,d}=C.$
	Ins.	Ins.	Ins.	Feet. Ins.	Sq. Ins.	Lbs.	Lbs.	
	—	1	1	1	1	2240	2240	2240
	—	1	1	4 6	1	500	2250	2250
	—	3	3	13 6	9	5080	63580	2540
	—	1	3	4 6	3	5100	22950	2550
	—	1	4	4 6	4	10300	46350	2896
	4 × 2	2	4	5	12	6720	33600	700
	1.52 × .78	1.56	4.07	4 6	2.35	6666	30000	3136
	1.5 × .5	.5	3	3 1	2	5208	16145	2676
	1.5 × .5	.5	3	3 1	2	4536	14062	2331
	1.5 × .5	.5	4	3 1	1	7104	22420	5475
	1.5 × .5	.5	4	3 1	1	3312	10267	2553
	1.53 × 1	.5	2.04	4	2.6	4004	16016	3019
	2 × .51	1	2.02	4	2.59	2569	10276	1963
	—	—	2.52	5	4.98	4143	20715	1650
	—	—	2.83	5	4	2988	14940	1320
	2.28 × .53	.3 / .425	5.13	4 6	2.28	9503	42763	3656
	23.9 × 3.12	3.29	36.1	20	183.5	403312	8066240	1220
	1.76 × .4	.29	5.13	4 6	2.82	6678	30512	2077
	1.74 × .26 / 1.78 × .55	.3	5.13	4 6	2.87	7368	33200	2250
	1.07 × .3 / 2.1 × .57	.32	5.13	4 6	3.02	8270	37215	2402
	1.54 × .32 / 6.5 × .51	.34	5.13	4 6	5.41	21009	94540	3406
	2.5 × 1.5 / 3.75 × 1.4	1.25	8.18	11	15	35620*	391853	3193

* Stirling iron.

:e, $\frac{A\,d\,C}{l}=W$. *A representing area of section, d depth in ins., l length in feet, destructive weight in lbs.*

—*When lengths are less than those instanced, breaking weight will be in consequence of increased stability of girder.*

To Compute Transverse Strength or Destructive Stress of Cast-iron Beams or Girders, of various Figures.

Supported at Both Ends. Weight applied in Middle.

When Section of Beam or Girder is alike to any of Examples given in preceding Table. Rule 1.*—Divide product of area of section and depth in ins., and *Coefficient* for girder, etc., from preceding Table, by length between supports in feet, and quotient will give breaking weight in lbs.

Example.—Dimensions of a beam, having top and bottom flanges in proportion of 1 to 6, give an area of section of 25.6 sq. ins., a depth of 15.5 ins., and a length between its supports of 18 feet; what is its destructive weight?

Note.—In consequence of increased area of metal over case No. 21 in Table, *Coefficient* of 3402 is reduced to 3300.

Dimensions.—Top flange, $3 \times .75$ *ins.*; bottom, $18 \times .75\ a = 13.5$ *sq. ins.*; web, $15.5 \times .7\ a' = 10.8$ *sq. ins.*, and $d' = 15.5 - .75 = 14.75$ *ins.*

$$\text{Then } \frac{25.6 \times 15.5 \times 3300}{18} = \frac{1\,309\,440}{18} = 72\,746.6 \textit{ lbs.}$$

D. K. Clark. $\dfrac{d'\,(6.5\dagger\, a + 2\, a')}{3\, l} = \text{W}$. *a representing area of bottom flange, a' of web at depth d' of beam, less depth of bottom flange in sq. ins., l length between supports in feet, and* W *destructive weight in tons.*

$$\text{Then } \frac{14.75\,(7 \times 13.5 + \overline{2 \times 10.8})}{3 \times 18} = \frac{1712.4}{54} = 31.71, \text{ which } \times 2240 = 71\,030.4 \textit{ lbs.}$$

Hodgkinson's formula would give a result of 53 491.2 *lbs.*, and Molesworth's 54 248.3 *lbs.*

Rule 2.—From product of breadth and square of depth in ins. of rectangular solid, the dimensions of which are the depth and greatest breadth of beam in its centre, subtract product of breadths and square of depths of that part of the beam which is required to make it a rectangular solid, and then determine its resistance by rule for the particular case as to its being supported or fixed, etc.

This rule is applicable only in case referred to, viz., when area of section is great compared with area of extreme dimensions.

Mr. Baker, in case of a hollow cylindrical shaft, where thickness of metal is but one eighth of extreme diameter, computes result at but .4 of that of a solid beam. This is in consequence of resistance to flexure in hollow beam being more than proportionally greater than in solid.

Example.—Take 7th case from preceding Table, page 813, for length of one foot. *Coefficient for cold-blast iron* = 500.

$$\text{Then } 1.52 \times 4.07^2 - \overline{1.52 \times 2.51^2} \times 4 \times 500 = (25.17 - 9.58) \times 2000 = 31\,180 \textit{ lbs.}$$

Result as by experiment, 30 000 *lbs.*

Note 1.—These rules are applicable to all cases where flange of beam is as shown in Table, and beam rests upon two supports, or *contrariwise*, as to position of flange, when beam is fixed at one end only.

2.—When case under consideration is alike in its general character to one in Table, but differs in some one or more points, an increase or decrease of metal is obtained by an increase or reduction of the *Coefficient*, according as the differences may affect resistance of beam.

3.—The *Coefficients* here given are based altogether upon experiments with English iron.

* Utility of these rules in preference to those of Hodgkinson, Fairbairn, Tredgold, Hughes, and Barlow is manifest, as in one case the *Coefficient* of the metal is considered, and in the other cases the metal is assumed to be of a uniform value or strength.

Only variable element not embraced in this rule is that consequent upon any peculiarity of form of ..., for instance, in that of a Hodgkinson, or like beam, where area of one flange greatly ex... of section, and this flange is other than below, when beam rests upon two supports or ... than above, when beam is fixed at one or both ends.

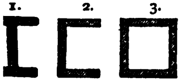
... to some extent by the three cases in table, where proportion of flanges are 1 to ...

† Coefficient same as tensile strength of metal in tons per sq. inch.

'langed Hollow or Annular Beams of Symmetrical Sections. (*D. K. Clark.*)

'hen Depth is Great Compared with Thickness of Flanges.—Figs. 1, 2, and 3.

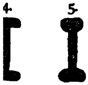
1. 2. 3.



$\frac{d \times S\,(4\,a + \overline{1.155\,a'})}{l} = W.$ *a representing area of one flange, a' area of web or ribs, both in sq. ins., d depth of beam, less depth of one flange, and l distance between supports, both in ins., S tensile strength of metal, and W weight between supports, both in lbs.*

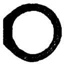
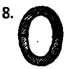
'hen Depth of Flanges is Great Compared with Depth of Beam.—Figs. 4 and 5.

4. 5.



$\frac{S\left(4\,a\frac{d'^2}{d} + \overline{1.155\,t\,d^2}\right)}{l} = W.$ *a representing area of one flange less thickness of web, in sq. ins., t thickness of web, d' reputed depth or distance between centres of flanges, and d depth of beam, all in ins.*

'hen Section of Circular or Elliptic Beam is Small Compared with Diameter.—Figs. 6, 7, and 8.

 $\frac{3.14\,d^2\,t\,S}{l} = W.$ 7.  8.  $\frac{1.57\,(b^2 + d^2)\,t\,S}{l} = W.$

and d representing mean breadth and depth.

ILLUSTRATION 1.—Assume Figs. 1, 2, and 3, 20 ins. in depth, width of flanges on p and bottom ribs 5 ins., thickness of flanges and webs 1 inch, and of sides of g. 3 .5 inch; length between supports 10 feet, and S 20000 lbs.; what would be eaking weight of each?

Then $\frac{20 - 1 \times 20000\,(4 \times 5 + \overline{1.155 \times 18})}{10 \times 12} = \frac{380000\,(20 + 20.79)}{120} = 129\,168.4$ *lbs.*

2.—Assume Figs. 4 and 5, 6 ins. in depth, area of flanges 3 ins., widths of webs 1 :h, and length and S as in preceding case.

'hen $\frac{20000\left(4 \times 3 \times \frac{\overline{6-1}^2}{6} + \overline{1.155 \times 1 \times 6^2}\right)}{10 \times 12} = \frac{20000 \times 91.58}{120} = 15\,263.3$ *lbs.*

3.—Assume Fig. 6 10 ins. in diameter, Fig. 7, 7.5 ins. in depth and 12 ins. in width, d Fig. 8, 12 ins. in depth and 7.5 ins. in width, and thickness of all metal 1 inch.

'hen, Fig. 6 $\frac{3.14 \times 10^2 \times 1 \times 20000}{10 \times 12} = \frac{6\,280\,000}{120} = 52\,333.3$* *lbs.*, which is .4 of at of solid cylinder.

Figs. 7 and 8 $\frac{1.57 \times (12^2 + 7.5^2) \times 1 \times 20000}{10 \times 12} = \frac{6\,287\,850}{120} = 52\,398.75$ *lbs.*

NOTE.—For all ordinary purposes, operation of computing their strength, by first mputing that of their circumscribing figure, and then deducting from it strength le to difference between it and section of beam under computation, will be suf- iently accurate. See Illustration, page 814.

If greater accuracy is required, see page 810, or *D. K. Clark's Manual*, pp. 513

NOTE.—To compute location of neutral axis of beams of unsymmetrical sect also *D. K. Clark*, pp. 514–15.

* This result agrees with deduction of Mr. Baker, as given by him in his work on Strength of B pp. 26–7, for hollow or annular beams of small area of section compared with that of dian up to a thickness of metal of one eighth of diameter. He assigns their strength so low as . of solid cylinder, in consequence of loss of resistance to flexure.

General Formulas for Destru… Beams of Symmetri…

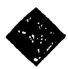
Supported at Both Ends. Weight …

Line of Neutral Axis runs through centre …

$\frac{2\,a\,d\,r\,S}{l} = W$, and $\frac{l\,W}{2\,a\,d\,r} = S$. In square be…

resenting area and depth of section, r radius of … l length of beam between its supports in ins., W … *and* S *tensile strength of material in like tons or …*

ILLUSTRATION.—Assume dimensions of cast-iro… follows, viz.: 1 and 2, 5 × 5 ins.; 3, 2.5 × 10; 4, … or equal areas; distance between supports 60 in… 20 000 lbs.

1.  2.  3

Areas of each 25 sq. ins. Radius of gyration, … .5; and 5, 1.43.

$$1.\quad \frac{2 \times 25 \times 10 \times .5775 \times 26\,0\ldots}{60}$$

$$2.\quad \frac{2 \times 25 \times 7.07^{*} \times .4083 \times 26\ldots}{60}$$

$$3.\quad \frac{2 \times 5^{2}\dagger \times .5775 \times 26\,000}{60} = \ldots$$

4. For formula for square beams s…

$$\text{Then } 4.\quad \frac{25 \times 5.64 \times 26\,000}{60} = 61\,100\ lbs.;$$

$$\frac{.7854 \times 4.39 \times 7.25^{2} \times 26\,00\ldots}{60}$$

These formulas give a result equal to a transve… a tensile strength of 26 000 lbs., and of *Wrought* … of 50 000 lbs. (as per table, page 788).

6.  7.  8. 

$\frac{C\,b\,d^2}{\ldots} = W$. C *representing coefficient of* … *nd depth in ins., l length in feet, and* W …

$\frac{\ldots^4 - r^4}{R}\ 4.7 = b\,d^2$. R *and r representin…*

$\frac{\ldots^3 - b'\,d'^3}{\ldots} = b\,d^2$. *b′ and d′ represen…*

$\frac{b\,d^2}{4} = W$. *d rep…*

and d representi… idth and depth of …

le strength of *Cast* … *Wrought Iron* of 5…

nt of Inertia of a Solid Beam.—Fig. 2.

2.  $\frac{b\,d^3}{12} = M.$

ents of preceding case.

$\frac{\times 20^3}{12} = \frac{64\,000}{12} = 5333.33$ *moment.*

enting breadth of vertical divisions, n number of hori- f neutral axis, b breadth, and d depth of beam.

nts of preceding case.

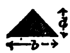
$t = 2$, $n = 5$, and $b = 8$.

0×2 *for lower half* $= 4800 =$ *moment.*

Beams of Various Figures.—Figs. 3, 4, 5.

3. $\frac{b\,d^3 - b'\,d'^3}{12}$, 4 and 5. $\frac{b\,d^3 - 2\,b'\,d'^3}{12} = M.$

b′ and d′ representing respectively breadth less thickness of web, and depth less thickness of flanges.

 $.7854\ c\ t^3 = M.$  $\frac{b\,d^3}{36} = M.$

 $\frac{s^4}{12} = M.$  $.11\ r^2 = M.$

:verse and c conjugate diameters, and s side.

on Centre of Gravity and Vertical Centres of Crushing and Tensile r or Beam.

of section of each part or figure composing tre from centre of one of the two extreme parts of their products by sum of surfaces of sec- ance of common centre of gravity from centres re.

re.

$$1 \times 0 \qquad = 2.5 \quad \times 0 \quad = .0$$

$$\left(\frac{5.62}{2} + \frac{1}{2}\right) = .325 \times 3.31 = 1.076$$

$$4 \times \left(\frac{.38}{2} + 5.62 + \frac{1}{2}\right) = 1.52 \quad \times 6.31 = 9.591$$

$$\overline{4.345} \qquad \overline{10.667}$$

.55 = *distance of common centre from centre of upper*

$$= 1.52 \quad \times 0 \quad = .0$$

$$\left(\frac{5.62}{2} + \frac{.38}{2}\right) = 1.826 \times 3 \quad = 5.478$$

$$\left(\frac{1}{2} + 5.62 + \frac{.38}{2}\right) = 2.5 \quad \times 6.31 = 15.775$$

$$\overline{5.846} \qquad \overline{21.253}$$

.31 = *distance of common centre from centre of low*

stance of common centre from bottom, and 3.631 +

centres of gravity

General Formulas for Destructive Weight of Solid Beams of Symmetrical Section.

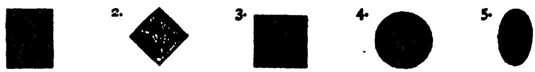
Supported at Both Ends. Weight applied in Middle.

Line of Neutral Axis runs through centre of gravity of section.

$\frac{2\,a\,d\,r\,S}{l} = W$, and $\frac{l\,W}{2\,a\,d\,r} = S$. In square beams for $a\,d$ put d^3. *a and d representing area and depth of section, r radius of gyration (half depth of beam = d), l length of beam between its supports in ins., W destructive weight in tons or lbs., and S tensile strength of material in like tons or lbs. per sq. inch.*

ILLUSTRATION.—Assume dimensions of cast-iron beams, Figs. 1, 2, 3, 4, and 5 as follows, viz.: 1 and 2, 5 × 5 ins.; 3, 2.5 × 10; 4, 5.64 diameter; and 5, 7.25 × 4.39, or equal areas; distance between supports 60 ins., and tensile strength of iron = 26 000 lbs.

1. 2. 3. 4. 5.



Areas of each 25 sq. ins. Radius of gyration, No. 1, .5775; 2, .4083; 3, .5775; 4, .5; and 5, 1.43.

1. $\frac{2 \times 25 \times 10 \times .5775 \times 26\,000}{60} = 125\,125$ *lbs.*

2. $\frac{2 \times 25 \times 7.07^{*} \times .4083 \times 26\,000}{60} = 62\,545$ *lbs.*

3. $\frac{2 \times 5^{3}\dagger \times .5775 \times 26\,000}{60} = 62\,562$ *lbs.*

4. For formula for square beams substitute $\frac{a\,d\,S}{l} = W$

Then 4. $\frac{25 \times 5.64 \times 26\,000}{60} = 61\,100$ *lbs.*; and for 5. $\frac{.7854\,b\,d^2\,S}{l} = W$.

$$\frac{.7854 \times 4.39 \times 7.25^2 \times 26\,000}{60} = 78\,532 \textit{ lbs.}$$

These formulas give a result equal to a transverse strength for *Cast iron* of 550 lbs. for a tensile strength of 26 000 lbs., and of *Wrought iron* of 600 lbs. for a like strength of 50 000 lbs. (as per table, page 788).

6. 7. 8. 9. 10.

$\frac{4\,C\,b\,d^2}{l} = W$. C *representing coefficient of strength of metal in lbs., b and d breadth and depth in ins., l length in feet, and W destructive weight in tons.*

6. $\frac{R^4 - r^4}{R}\,4.7 = b\,d^2$. R *and r representing external and internal radius.*

$\frac{b\,d^3 - b'\,d'^3}{d} = b\,d^2$. *b′ and d′ representing interior breadth and depth.*

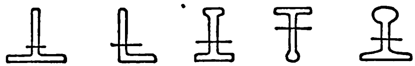
$38\,R^3 = b\,d^2$. 9. $\frac{b\,d^2}{4} = W$. *d representing depth or height.*

$d'^2 = W$. *b and d representing breadth and depth of centre and … and d′ breadth and depth of horizontal rib, external to central rib.*

… r a tensile strength of *Cast Iron* of 26 000 lbs. per sq. inch, and … ngth of *Wrought Iron* of 50 000 lbs., and *pro rata.*

… nal of square. † In square beams $d^3 = a \times d$.

Beams of Unsymmetrical Section. (*D. K. Clark.*)



S *representing total tensile strength of section in lbs. per sq. inch, d*

nce between centres of tension and compression in ins., l length in ins.,
: in lbs.

ɔN.—If the sectional area of a beam of cast iron is 5.9 sq. ins., the ınce between centres of tension and compression 5.6 ins., distance be- ts 5.5 feet, and tensile strength of metal 30000 lbs. per sq. inch.

Then $\frac{4 \times 5.9 \times 30000 \times 5.6}{5.5 \times 12} = \frac{3964800}{66} = 60072.7$ *lbs.*

STEEL.

mpute Transverse Strength of Steel Bars.

Supported at Both Ends. Weight applied in Middle.

= W. S *representing tensile strength in lbs., l length between supports*
7 weight in lbs.

ɔN.—What is ultimate destructive stress of a bar of Crucible steel, and 2 feet between supports? S = 90000 lbs.

Then $\frac{1.155 \times 90000 \times 2^3}{2 \times 12} = \frac{831600}{24} = 34650$ *lbs.*

ɔute Section of Lower Flange of a Girder or .rical Shaft of Cast Iron to Sustain a Safe Load Middle. (*Baker.*)

l representing distance between supports in feet, d depth of girder, etc.,
'ght in tons, C *coefficient, and* M *moment of weight around support.*

ɔN.—What should be section of a girder, 12 ins. deep, to sustain a safe s in its middle, between supports 16 feet apart?

ned 2 tons per sq. inch, and Factor of safety 4. $\frac{16 \times 12 \times 10}{4} = 480 = M.$

$= a.$ S *representing stress assumed in tons, and a area of section of*
ins. Then $\frac{480}{12 \times 2} = 20$ *sq. ins.*

angular, Diagonal, or Circular Beam or Shaft.

$\frac{d^2 b}{6} = M.$  $\frac{d^3}{10.2} = M.$  $\frac{d^3}{8.4} = M.$

Formulas for Computation of Destructive t of a Beam or Girder of any form of Cross ı and of any Material. (*B. Baker.*)

Load applied at Middle.

= W. S *representing tensile strength of material per sq. inch in tons,*

resistance of section = product of effective depth of girder or beam, and of flange portion of section, in sq. ins., Q *resist ... ure, l dis- supports in feet, and* Q′ = Q × *thickness of w ... ins.*

Average Values of S *for Various Ma*

	Tons.		Tons.	
....	7	Steel	40 to 50	O
....	21	" plates	35	P.

Substituting Values of S and Q in a General Equation.

Section.	Cast Iron.	Wrought Iron.	Steel.	Oak.	Pine.
■	$W = .875 \frac{d^2 b}{l}$	$= 1.75 \frac{d^2 b}{l}$	$= 3$ to $5 \frac{d^2 b}{l}$	$= .14$ to $.25 \frac{d^2 b}{l}$	$= .11$ to $.2 \frac{d^2 b}{l}$
◆	$W = .75 \frac{d^3}{l}$	$= 1.5 \frac{d^3}{l}$	$= 2.625$ to $4.25 \frac{d^3}{l}$	$= .1$ to $.16 \frac{d^3}{l}$	$= .08$ to $.14 \frac{d^3}{l}$
●	$W = .5625 \frac{d^3}{l}$	$= 1.125 \frac{d^3}{l}$	$= 2$ to $3.25 \frac{d^3}{l}$	$= .08$ to $.14 \frac{d^3}{l}$	$= .06$ to $.11 \frac{d^3}{l}$

d representing depth of a rectangular bar, side of a square, or diameter of a round, b breadth of a vertical bar, all in ins., and l distance between supports in feet.

Moment of Resistance.

Moment of Resistance of a cross section is the static force resisting an external force of tension or compression, and it is equal to moment of *Inertia*, divided by distance of centre of effect of the area of fibres which are respectively the most extended or compressed from the *neutral axis* of the section.

To Compute Moment of Resistance.

$\frac{I}{d} = M$. I *representing moment of inertia, and d distance of centre of effect of area of fibres of extension or compression.*

Work of Resistance.

Under a Quiescent Load.—Intensity of Elastic resistance increases uniformly with total space through which action of stress operates; hence, it may be defined by a triangular section.

Consequently, $.5\, s\, L = R$. *s representing space passed through*, L *load, and* R *resistance.*

To Compute Moment of Resistance.

$\frac{6\,C\,I}{h}$ and $\frac{M\,I}{h} = R$. C *a coefficient = one sixth of destructive weight*, I *moment of inertia, h height of neutral axis from base of section*, R *moment of resistance, and* M *modulus of rupture.*

Note.—Neutral axis, for all practical purposes, is at centre of gravity of any section.

For *Radius of Gyration*, see Centre of Gyration, page 609.

For other rule for computation of Moment of Resistance, see Strength of Beams, *B. Baker*, London, 1870.

Moment of Inertia.

Moment of Inertia is resistance of a beam to bending, and moment of any transverse section is equal to sum of products of each particle of its area into square of their distance from neutral axis of section.

1.

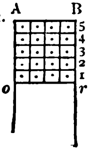


Illustration.—If transverse section of a beam, A B C D, Fig. 1, is 8 × 20 ins., its neutral axis will be at middle of its depth, *o r*; divide A B, *o r*, into any number of equal spaces, as shown, then each space will be 2 × 2 = 4 sq. ins., and the distances of the centre of each square from neutral axis will be as follows:

1, 1.	$2 \times 2 \times 4 \times 1^2 = 16$	4, 4.	$2 \times 2 \times 4 \times 7^2 = 784$
2, 2.	$2 \times 2 \times 4 \times 3^2 = 144$	5, 5.	$2 \times 2 \times 4 \times 9^2 = 1296$
3, 3.	$2 \times 2 \times 4 \times 5^2 = 400$		

2640×2 for lower half $= 5280 =$ *moment.*

he area of the figure in illustration had been more minutely divided ıld have approximated more nearly to the above result.

of Inertia of a Revolving ... see Centre of Gyration, page 609.

ompute Moment of Inertia of a Solid Beam.—Fig. 2.

2.  $\frac{b\,d^3}{12} = M.$

ᴛʀᴀᴛɪᴏɴ.—Take elements of preceding case.

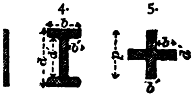
$$\text{Then } \frac{8 \times 20^3}{12} = \frac{64\,000}{12} = 5333.33 \textit{ moment.}$$

; $t^3\, n^3\, b = M.$ *t representing breadth of vertical divisions, n number of hori- ivisions from plane of neutral axis, b breadth, and d depth of beam.*

ᴛʀᴀᴛɪᴏɴ.—Take elements of preceding case.

$$t = 2,\ n = 5, \text{ and } b = 8.$$

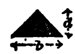
$.3 \times 2^3 \times 5^3 \times 8 = 2400 \times 2$ *for lower half* $= 4800 =$ *moment.*

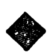
4. 5. 

Beams of Various Figures.—Figs. 3, 4, 5.

$$3.\ \frac{b\,d^3 - b'\,d'^3}{12},\ 4 \text{ and } 5.\ \frac{b\,d^3 - 2\,b'\,d'^3}{12} = M.$$

b′ and d′ representing respectively breadth less thickness of web, and depth less thickness of flanges.

 $.7854\, r^4 = M.$  $.7854\, c\, t^3 = M.$  $\frac{b\,d^3}{36} = M.$

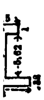
$.7854\,(r^4 - r'^4) = M.$  $\frac{s^4}{12} = M.$  $.11\, r^2 = M.$

resenting radius, t transverse and c conjugate diameters, and s side.

ompute Common Centre of Gravity and Vertical stance between Centres of Crushing and Tensile ress of a Girder or Beam.

ᴇ.—Multiply surface of section of each part or figure composing by distance of its centre from centre of one of the two extreme parts res, as •; divide sum of their products by sum of surfaces of sec- id result will give distance of common centre of gravity from centres ı extreme part or figure.

ᴘʟᴇ.—Take annexed figure.



$$\textit{Above}\begin{cases} 2.5 \times 1 \times 0 & = 2.5 \times 0 = .0 \\ .325 \times \left(\frac{5.62}{2} + \frac{1}{2}\right) & = .325 \times 3.31 = 1.076 \\ .38 \times 4 \times \left(\frac{.38}{2} + 5.62 + \frac{1}{2}\right) & = 1.52 \times 6.31 = 9.591 \\ & \quad \overline{4.345} \qquad \overline{10.667} \end{cases}$$

ing 10.667 by $4.345 = 2.455 =$ *distance of common centre from centre of upper*

$$\textit{Below}\begin{cases} 1.52 \times 0 & = 1.52 \times 0 = .0 \\ 325 \times 5.62 \times \left(\frac{5.62}{2} + \frac{.38}{2}\right) & = 1.826 \times 3 = 5.478 \\ 2.5 \times \left(\frac{1}{2} + 5.62 + \frac{.38}{2}\right) & = 2.5 \times 6.31 = 15.775 \\ & \quad \overline{5.846} \qquad \overline{21.253} \end{cases}$$

ing 21.225 by $5.846 = 3.631 =$ *distance of common centre from centre of*

, $3.631 + \frac{.38}{2} = 3.821 =$ distance of common centre from bottom, and

$.283 =$ distance between centres of gravity.

Girders, Beams, Lintels, etc.

Transverse or Lateral Strength of any Girder, Beam, Breast-summer, Lintel, etc., is in proportion to product of its breadth and square of its depth, and area of its cross-section.

Best form of section for Cast-iron girders or beams, etc., is deduced from experiments of Mr. E. Hodgkinson, and such as have this form of section ⊥ are known as Hodgkinson's.

Rule deduced from his experiments directs, that *area of bottom flange should be* 6 *times that of top flange*—flanges connected by a thin vertical web, sufficiently rigid, however, to give the requisite lateral stiffness, tapering both upward and downward from the neutral axis; and in order to set aside risk of an imperfect casting, by any great disproportion between web and flanges, it should be tapered so as to connect with them, with a thickness corresponding to that of flange.

As both Cast and Wrought iron resist compression or crushing with a greater force than extension, it follows that the flange of a girder or beam of either of these metals, which is subjected to a crushing strain, according as the girder or beam is *supported at both ends, or fixed at one end*, should be of less area than the other flange, which is subjected to extension or a tensile stress.

When girders are subjected to impulses, and sustain vibrating loads, as in bridges, etc., best proportion between top and bottom flange is as 1 to 4; as a general rule, they should be as narrow and deep as practicable, and should never be deflected to more than .002 of their length.

In Public Halls, Churches, and Buildings where weight of people alone are to be provided for, an estimate of 175 lbs. per sq. foot of floor surface is sufficient to provide for weight of flooring and load upon it. In computing other weight to be provided for it should be that which may at any time bear upon any portion of their floors; usual allowance, however, is for a weight of 280 lbs. per sq. foot of floor surface for stores and factories.

In all uses, such as in buildings and bridges, where the structure is exposed to sudden impulses, the load or stress to be sustained should not exceed from .2 to .16 of breaking weight of material employed; but when load is uniform or stress quiescent, it may be increased to .3 and .25 of breaking weight.

An open-web girder or beam, etc., is to be estimated in its resistance on the same principle as if it had a solid web. In cast metals, allowance is to be made for loss of strength due to unequal contraction in cooling of web and flanges.

In Cast Iron, the mean resistances to Crushing and Extension are, for American as 4.55 to 1, and for English as 5.6 to 7 to 1; and in Wrought Iron are, for American as 1.5 to 1, and for English as 1.2 to 1; hence the mass of metal below neutral axis will be greatest in these proportions when stress is intermediate between ends or supports of girders, etc.

Wooden Girders or *Beams*, when sawed in two or more pieces, and slips are set between them, and whole bolted together, are made stiffer by the [illegible]tion, and are rendered less liable to decay.

[illegible]ers cast with a face up are stronger than when cast on a side, in the [illegible]ion of 1 to .96, and they are strongest also when cast with bottom [illegible]

[illegible]mical construction of a Girder or Beam, with reference to its [illegible]trength with least material, is as follows: The outline of

tom, and sides should be a curve of various forms, according as . or depth throughout is equal, and as girder or beam is loaded only ɪnd, or in middle, or uniformly throughout.

king Weights of Similar Beams are to each other as Squares of their ɪear Dimensions.

ɪoard of Trade regulations in England, iron may be strained to 5 tons inch in tension and compression, and by regulation of the Ponts et ées, France, 3.81 tons.

ts .75 and 1 inch in diameter, and set 3 ins. from centre in top of and 4 ins. at bottom.

acter of fracture, as to whether it is crystalline or fibrous, depends haracter of blows; thus, sharp blows will render it crystalline, and ill not disturb its fibrous structure.

spans exceeding 40 feet, wrought iron is held to be preferable to n.

ting, when well executed, is not liable to be affected by impact or r of load.

upled Girder or *Beam* is one composed of two, fastened together, and over the other.

Trussed Beams or Girders.

ght and Cast Iron possess different powers of resistance to tension and com-ı; and when a beam is so constructed that these two materials act in uni-h each other *at stress due to load required to be borne*, their combination will n essential economy of material. In consequence of the difficulty of adjust-nsion-rod to the stress required to be borne, it is held to be impracticable to ct a perfect truss beam.

ɪairn declares that it is better for tension of truss-rod to be low than high, ɔosition is fully supported by following elements of the two metals ·

ght Iron has great tensile strength, and, having great ductility, it undergoes longation when acted upon by a tensile force. On the contrary, *Cast Iron* at crushing strength, and, having but little ductility, it undergoes but little ion when acted upon by a tensile stress; and, when these metals are re-from the action of a high tensile stress, the *set* of one differs widely from the other, that of wrought iron being the greatest.

r same increase of temperature, expansion of wrought is considerably great-that of cast iron; 1.81* tons per sq. inch is required to produce in wrought ne extension as in cast iron by 1 ton.

ɪairn, in his experiments upon English metals, deduced that within limits ss of 13 440 lbs. per sq. inch for cast iron, and 30 240 lbs. per sq. inch for ıt iron, tensile force applied to wrought iron must be 2.25 times tensile force to cast iron, to produce equal elongations.

ive tensile strengths of cast and wrought iron being as 1 to 1.35, and their ıce to extension as 1 to 2.25, therefore, where no initial tension is applied to rod, cast iron must be ruptured before wrought iron is sensibly extended.

tance of cast iron in a trussed beam or girder is not wholly that of tensile h, but it is a combination of both tensile and crushing strengths, or a trans-trength; hence, in estimating resistance of a trussed beam or girder, trans-trength of it is to be used in connection with tensile strength of truss.

: transverse strength of a cast-iron bar, one inch square and or supported at both ends, stress applied in the middle, *without se* ; and as mean tensile strength of wrought iron, also *without se* bs. per sq. inch, ratio between sections of beams and of truss sh ' transverse strength per sq. inch of beam and of tensile strength c

ırs under consideration are those alone in which truss is attache ɪwer flange, in which case it presents following conditions:

---

* Elongation of cast and wrought iron being 5500 and 10 000, hence 10 000 ÷ 5500 = 1.8

1. *When truss runs parallel to lower flange.* 2. *When truss runs at an inclination to lower flange, being depressed below its centre.* 3. *When beam is arched upward, and truss runs as a chord to curve.*

Consequently, in all these cases section of beam is that of an open one with a cast-iron upper flange and web, and a wrought-iron lower flange, increased in its resistance over a wholly cast-iron beam in proportion to the increased tensile strength of wrought iron over cast iron for equal sections of metals.

From various experiments made upon trussed beams, it is shown:

1. That their rigidity far exceeds that of simple beams; in some cases it was from 7 to 8 times greater. 2. That when truss resists rupture, upper flange of beam being broken by compression, there is a great gain in strength. 3. That their strength is greatly increased by upper flange being made larger than lower one. 4. That their strength is greater than that of a wrought-iron tubular beam containing same area of metal.

Comparative Value of Wrought-iron Bars, Hollow Girders, or Tubes of Various Figures (*English*).

Circular tubes, riveted	1	Circular, uniform thickness	1.7
Flanged beams	1.2	Plate beams	1.7
Elliptic tubes, riveted	1.3	Elliptic, uniform thickness	1.8
Rectangular tubes, riveted	1.5	Rectangular, uniform thickness	2

General Deductions from Experiments of Stephenson, Fairbairn, Cubitt, Hughes, etc.

Fairbairn shows in his experiments that with a stress of about 12 320 lbs. per sq. inch on cast iron, and 28 000 lbs. on wrought iron, the sets and elongations are nearly equal to each other.

A cast-iron beam may be bent to .3 of its breaking weight if load is laid on gradually; and .16 of it, if laid on at once, will produce same effect, if weight of beam is small compared with weight laid on. Hence, beams of cast iron should be made capable of bearing more than 6 times greatest weight which will be laid upon them.

In beams of cast or wrought iron, if fixed or supported at both ends, flanges should be in proportion to relative resistances of material to crushing or extension.

Breaking weights in similar beams are to each other as squares of their like linear dimensions; that is, breaking weights of beams are computed by multiplying together area of their section, depth, and a *Constant*, determined from experiments on beams of the particular form under investigation, and dividing product by distance between supports.

Cast and wrought-iron beams, having similar resistances, have weights nearly as 2.44 to 1.

A box beam or girder, constructed of plates of wrought-iron, compared to a single rib and flanged beam I, of equal weights, has a resistance as 100 to 93.

Resistance of beams or girders, where depth is greater than their breadth, when supported at top, is much increased. In some cases the difference is fully one third.

When a beam is of equal thickness throughout its length, its curve of equilibrium, to enable it to support a uniform stress with equal resistance in every part, should be an *Ellipse*, and if beam is an open one, its curve of equilibrium, for a uniform load, should be that of a *Parabola*. Hence, when middle portion is not wholly removed, its curve should be a compound of an ellipse and a parabola, approaching nearer to the latter as the middle part is decreased.

Girders of cast iron, up to a span of 40 feet, involve a less cost than of wrought iron.

...st-iron beams and girders should not be *loaded* to exceed .2, or subjected to a ...r stress than .166 of their destructive weight; and when the stress is attended ...ncussion and vibration, this proportion must be increased.

...le cast-iron girders may be made 50 feet in length, and best form is that of ... when subjected to a fixed load, flanges should be as 1 to 6, and when ...as 1 to 4.

...nces exceeding limit of those of simple cast iron are vari...ted are those of straight or arched cast-iron girders in ...d together—Trussed, Bowstring, and wrought-iron Box

Straight or *Arched Girder*, formed of separate castings, is entirely dependent on bolts of connection for its strength.

Trussed or *Bowstring Girder* is made of one or more castings to a single piece, d its strength depends, other than upon the depth or area of it, upon the proper justment of the tension, or the initial strain, upon the wrought-iron truss.

Box or *Tubular Girder* is made of wrought iron, and is best constructed with st-iron tops, in order to resist compression: this form of girder is best adapted to ord lateral stiffness.

When a girder has four or more supports, its condition as regards a stress on its middle is essentially that of a beam fixed at both ends.

The following results of the resistances of materials will show how they ould be distributed in order to obtain *maximum* of strength with *minimum* dimensions:

	To Tension.	To Crushing.		To Tension.	To Crush'g.
ist iron.........	21 000	90 300	Oak, white, mean.	11 000	7 500
	32 000	140 500	" English " .	6 500	3 100
" English..	13 000	58 000	Wrought iron.....	45 000	47 000
	23 000	116 000		59 000	83 000
ranite...........	578	15 000	" English	31 000	40 000
imestone........	670	4 000		53 000	65 000
	2 800	9 000	Yellow pine......	16 000	4 000

The best iron has greatest tensile strength, and least compressive or crushing.

'onditions of Forms and Dimensions of a Symmetrical Beam or Girder.

When Fixed at One End, and Loaded at the Other.

1. *When Depth is uniform throughout entire Length*, section at every point iust be in proportion to product of length, breadth, and square of depth, and s square of depth is in every point the same, breadth must vary directly as ngth; consequently, each side of beam must be a vertical plane, tapering radually to end.

2. *When Breadth is uniform throughout entire Length*, depth must vary s square root of length; hence upper or lower sides, or both, must be deterined by a parabolic curve.

3. *When Section at every point is similar, that is, a Circle, an Ellipse, a 'quare, or a Rectangle, Sides of which bear a fixed Proportion to each other*, ie section at every point being a regular figure, for a circle, the diameter every point must be as cube root of length; and for an ellipse or a recngle, breadth and depth must vary as cube root of length.

ILLUSTRATION.—A rectangular beam as above, 6 ins. wide and 1 foot in depth at extreme end, and 4 feet in length, is capable of bearing 6480 lbs.; what should its dimension at 3 feet? $\sqrt[3]{4} = 1.587$, and $\sqrt[3]{3} = 1.442$.

Then $1.587 : 1.442 :: 1 : .9086$, and 6 and $12 \times .9086 = 5.452$ and 10.9.

$$\text{Hence } \frac{5.452 \times 10.9^2}{3} = 216, \text{ and } \frac{6 \times 12^2}{4} = 216.$$

Vhen Fixed at One End, and Loaded uniformly throughout its Length.

1. *When Depth is uniform throughout its entire Length*, breadth r rease as the square of length.

2. *When Breadth is uniform throughout its entire Length*, depth v irectly as length.

3. *When Section at every point is similar, as a Circle, Ellipse, Squ ectangle*, section at every point being a regular figure, cube of dep in ratio of square of length.

ILLUSTRATION.—Take preceding case.

Then $4^2 : 3^2 :: 12^3 : 972$, and $\sqrt[3]{972} = 9.9$ *in depth.*

When Supported at Both Ends.

1. *When Loaded in the Middle, Coefficient* or *Factor of Safety* of the beam, or product of breadth and square of depth, must be in proportion to distance from nearest support; consequently, whether the lines forming the beam are straight or curved, they meet in the centre, and of course the two halves are alike.

2. *When Depth is Uniform throughout,* breadth must be in ratio of length.

3. *When Breadth is Uniform throughout,* depth will vary as square root of length.

4. *When Section at every point is similar, as a Circle, Ellipse, Square, and Rectangle,* section at every point being a regular figure, cube of depth will be as square of distance from supported end.

When Supported at Both Ends, and Loaded uniformly throughout its Length.

1. *When Depth is Uniform,* breadth will be as product of length of beam and length of it on one side of given point, less square of length on one side of given point.

2. *When Breadth is Uniform,* depth will be as square root of product of length of beam and length of it on one side of given point, less square of length on one side of given point.

3. *When Section at every point is similar, as a Circle, Ellipse, Square, and Rectangle,* section at every point being a regular figure, cube of depth will be as product of length of beam and length of it on one side of given point, less square of length on one side of given point.

Elliptical-sided Beams.

To Determine Side or Curve of an Elliptical-sided Beam.

$\sqrt{\frac{L\,l}{2\,C\,b}} = d.$ L *representing load in lbs., l length in feet,* C *coefficient, and b breadth in ins.*

ILLUSTRATION.—What should be depth in centre of a beam of white pine, 10 feet in length between its supports, and 5 ins. in breadth, to support a load of 10000 lbs.?

$$\text{Assume } C = 100. \quad \text{Then } \sqrt{\frac{10\,000 \times 10}{2 \times 100 \times 5}} = \sqrt{\frac{100\,000}{1000}} = 10 \textit{ ins.}$$

Hence, outline of beam is that of a semi-ellipse, having 10 feet for its transverse diameter, and 9 ins. for its semi-conjugate.

NOTE.—Weight of Girder, Beam, etc., should in all cases be added to stress or load

Miscellaneous Illustrations.

-What should be side of a rectangular white oak beam, 2 ins. in width, and 6 etween its supports, to sustain a load of 360 lbs.?

stress at .2 of breaking weight of 150 lbs. = 30.

$$\sqrt{\frac{6 \times 360}{4 \times 2 \times 30}} = \sqrt{\frac{2160}{240}} = 3 \textit{ ins.}$$

d be breadth and depth of such a beam if square?

$$\sqrt[3]{\frac{6 \times 360}{4 \times 30}} = \sqrt[3]{\frac{2160}{120}} = 2.62 \textit{ ins.}$$

er of a cylinder?

$$\text{nd } \sqrt[3]{\frac{120}{4}} = 3.1 \textit{ ins.}$$

STEEL.

To Compute Transverse Strength of Steel Bars.

Supported at Both Ends. Weight applied in Middle.

$\frac{1.155\, S\, b\, d^2}{l} = W$. S *representing tensile strength in lbs.*, *l length between suppor in ins.*, *and* W *weight in lbs.*

ILLUSTRATION.—What is ultimate destructive stress of a bar of Crucible stee 2 ins. square, and 2 feet between supports? S = 90 000 lbs.

$$\text{Then } \frac{1.155 \times 90\,000 \times 2^3}{2 \times 12} = \frac{831\,600}{24} = 34\,650 \textit{ lbs.}$$

Elastic Transverse Strength is 50 per cent. of its ultimate strength.

Hardening in oil increases its strength from 12 to 56 per cent. Thus,

Soft steel, 121 520 lbs.; soft steel, cooled in water, 90 160 lbs.; soft stee cooled in oil, 215 120 lbs.

Krupp's is about .45 of its tensile breaking weight, .24 of its compressiv or crushing strength, .38 of its transverse, and .39 of its torsional.

Friction of a steel shaft compared to one of wrought iron is as .625 to 1.

Capacity of steel to resist a transverse stress is much less than to resis torsion.

Relative diameters of steel and wrought-iron shafts, to resist equal trans verse stress, are as .98 to 1, and weight of such a proportion of steel shai compared with one of wrought iron will be about 4 per cent. less, and frictio of bearing will be 6 per cent. less.

CYLINDERS, FLUES, AND TUBES.

Hollow Cylinders. Cast Iron.

To Compute Elements of Hollow Cylinders within Limits of Elastic Strength. (*D. K. Clark.*)

$S \times hyp.\ log.\ R = P$. $\frac{P}{hyp.\ log.\ R} = S$. $\frac{P}{S} = hyp.\ log.\ R$. S *representin elastic tensile strength of metal in lbs. per sq. inch*, R *ratio of external diameter to in ternal*, $= \frac{d'}{d} = \frac{r'}{r}$, *and* P *internal pressure in lbs. per sq. inch. d and d' representin internal and external diameter, and r and r' internal and external radii, all in ins*

NOTE.—Hyperbolic Logarithm of a number is equal to product of its common logarithm and 2.3026

ILLUSTRATION 1.—Diameters of a hydrostatic cylinder 5.3 by 13.125 ins.; wh pressure within its elastic strength will it sustain per sq. inch?

$$\text{Assume } S = 10\,000 \textit{ lbs. Hyp. log. } R = \frac{13.125}{5.3} \times 2.3026 = \log. 2.5 \times 2.3026 = .92.$$

$$\text{Then } 10\,000 \times .92 = 9200 \textit{ lbs. per sq. inch.}$$

NOTE.—For Bursting Strength take maximum strength of metal.

2.—A water-pipe .75 inch thick has an internal diameter of 10 ins., what is it bursting pressure?

$$S = 30\,000 \text{ lbs. } \textit{Hyp. log.} \frac{10 + \overline{.75 \times 2}}{10} = .1398.$$

Then $30\,000 \times .1398 = 4194$ *lbs.*

3.—If it were required of a hydrostatic press to sustain a pressure of r upon a ram of 5 ins. in diameter, what would be pressure on ram, and w be thickness of metal, assuming it equal to an elastic tensile stress of per sq. inch?

Area of 5 ins. = 19.635. $\frac{589\,050}{19.635} = 30\,000 =$ *pressure per sq. inch on*

Then $\frac{30\,000}{15\,000} = 2$, which $= hyp.\ log.\ R = 7.39$, and $7.39 \times 5 = 36.95 =$ *ex ameter.* $36.95 - 5 = 31.95$, which $\div 2 = 15.975$ *ins. thickness of metal.*

Wrought Iron and Steel.

$$\frac{R + hyp.\ log.\ \frac{d'}{d} - 1}{2} S = P. \qquad \frac{2\,P}{R + hyp.\ log.\ \frac{d'}{d} - 1} = S. \qquad \frac{2\,P}{S} + 1 = (P + hyp.\ log$$

ILLUSTRATION 1.—If diameters of a wrought-iron cylinder are 5 and 15 ins., and ultimate or destructive strength of metal is 40 000 lbs. per sq. inch, what is its bursting pressure?

$$\frac{15}{5} = 3. \quad Hyp.\ log.\ 3 = .477\,12 \times 2.3026 = 1.0986.$$

Then $\frac{3 + 1.0986 - 1}{2} \times 40\,000 = 61\,972$ *lbs. per sq. inch* $= 61\,972 \times 5 \div \overline{15-5} =$ 30 986.2 *lbs. per sq. inch of section of metal.*

2.—A steam-boiler 6 feet in internal diameter, of wrought-iron plates .375 inch thick and double riveted longitudinally, burst at a joint by a pressure of 300 lbs. per sq. inch; what was resistance of joint per sq. inch of its section?

$$\frac{72 + \overline{.375 \times 2}}{72} = 1.0104. \quad Hyp.\ log.\ 1.0104 = .010\,345.$$

Then $\frac{2 \times 300}{1.0104 + .010\,345 - 1} = \frac{600}{.020\,745} = 29\,405$ *lbs. per sq. inch of section of joint.*

SHIP AND BOILER PLATES.

(*See pages 751–757 for Boiler Riveting.*)

Ultimate Tensile Strength of Riveted and Welded Joints of Wrought-iron Plates. (*D. K. Clark.*)

Entire Plate = 100.

JOINTS.	Plate. .5	Plate. .375	Plate. .4375	Average.
Scarf-welded	—	102	106	104
Lap-welded	50	66	69	62
Single hand riveted	40	60	50	50
" " snap-headed	50	56	52	53
" " by machine	40	52	54	49
" " counter-sunk head	44	52	50	49
Double riv'd, snap-headed	59	72	70	[illegible]
" " counter-sunk and snap-headed	53	69	72	[illegible]
" " with single welt, counters'k and snap-headed	52	65	60	[illegible]

Strength of Riveted Joints per Sq. Inch of Single Plate. (*Wm. Fairbairn.*)

Single Lapped.—Machine riveted. Pitch 3 times, 25 000 lbs.

Hand riveted. Pitch 3 times, 24 000 lbs.

Rivets "staggered," and equidistant from centres, 30 500 lbs.

Abut Joints.—Hand riveted. Rivets not "staggered," and equidistant from centres, single cover or strap, 30 000 lbs.

Rivets "square," single cover or strap, 42 000 lbs.; double covers or straps, 55 000 lbs.

Comparative Strength of Riveted Joints.

Entire Plate .375 *ins. thick* = 100.

Double riveted, double strap, or fish-plated joint	80	Double riveted, single strap, or fish-plated joint	[illegible]
Double riveted lap joint	72	Single riveted lap joint	[illegible]

For all joints of plates over .5 inch, other than double welded, these proportions are too high.

A closer pitch of rivets should be adopted in single than in double riveted, etc.

Dimensions of Rivets, Pitch, Lap, etc.

e. ness.	Diam. of Rivet.	Length from Head.	Pitch.	Lap. Single.	Lap. Double.	Lap. Staggered.
1.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
	.5	1.125	1.5	1.5625	2.75	2.4375
25	.625	1.375	1.625	2	3.4375	3
5	.75	1.625	1.75	2.4375	4.125	3.625
	.8125	2.25	2.125	2.625	4.4375	3.9375
25	.9375	2.75	2.375	3	5.1875	4.5625
5	1	3	2.625	3.25	5.5	4.8125
	1.125	3.25	3	3.625	6.1875	5.4375
5	1.25	4	3.375	4	6.875	6.0625
	1.5	4.5	4.375	4.875	8.25	7.25

ps. —Single, .125 thicker than the plate; Double, each .625 of thickness of

To Compute Diameter of Rivet.

linarily, T 1.25 + .1875 = *d.* T *representing thickness of plate, and d diameter t.*

Pitch of Rivets. (*Nelson Foley.*)

s.	Metal between the Holes.	Diam. of Rivets.	Plates.	Metal between the Holes.	Diam. of Rivets.
....	52 to 62 per cent.	1.4 to 2.3	Square..	70 to 78 per cent.	.99 to 1.7
red.	68 to 75 " "	1.4 to 2.1	Triple...	76 to 80 " "	.77 to 1

portions of Single Rivet Wrought-iron Joints. (*French.*)

ss .	Diameter of Rivets.		Pitch of Rivets.		Width of Lap.		Thickness of Plate.		Diameter of Rivets.		Pitch of Rivets.		Width of Lap.	
h.	Mil's	Inch.	Mil's	Ins.	Mil's	Ins.	Mil's	Inch.	Mil's	Ins.	Mil's	Ins.	Mil's	Ins.
18	8	.315	27	1.06	30	1.18	10	.394	20	.787	56	2.2	58	2.28
58	10	.394	32	1.26	34	1.34	11	.433	21	.827	57	2.24	60	2.36
97	12	.472	37	1.46	40	1.58	12	.472	22	.866	58	2.28	60	2.36
36	14	.551	43	1.69	44	1.73	13	.512	23	.906	60	2.36	62	2.44
76	16	.63	48	1.89	50	1.97	14	.551	24	.945	62	2.44	64	2.52
15	17	.669	51	2.01	54	2.13	15	.591	25	.984	63	2.48	66	2.6
54	19	.748	54	2.13	56	2.2	16	.63	26	1.024	65	2.56	68	2.68

lt of Experiments on Double Riveted and Double Strapped Plate Joints. (*Mr. Brunel.*)

20 *ins. in width,* 5 *inch thick, Abut jointed, with a Strap or Fish-plate on each side,* 10 *ins. in width. Holes Punched.*

.6875 inch rivets, 4 ins. pitch, set "square," tensile strength 77 per cent.
.75 " " " " "staggered," " " 78.6 "
.75 " " 5 " " "square," " " 84 "

Boiler Riveting see pp. 755-57.

Hulls of Vessels.

Diameter of Rivets.

Plate.	U. S. and British Lloyds.	Liverpool Reg'y.	Admiralty, Eng.	Millwall, Eng.	Pitch of Rivets.	Length of Rivets. Counter-sunk.	Snap-headed.
Inch.	Inch.	Ins.	Ins.	Inch.	Ins.	Ins.	Ins.
.3125	.625	.5	.5	.625	1.75	1.125	1.5
.375	.625	.625	.625	.625	2	1.25	1.625
.4375	.625	.625	.75	.625	2.125	1.375	1.75
.5	.75	.75	.75	.75	2.25	1.5	2
.5625	.75	.75	.875	.75	2.437	1.6875	2.1875
.625	.75	.8125	.875	.875	2.56	1.9375	2.375
.6875	.875	.875	.875	.875	2.812	2.1875	2.5625
.75	.875	.875	1	.875	3.125	2.375	2.75
.8125	.875	.9375	1	.875	3.375	2.5	2.875
.875	1	1	1.125	1	3.625	2.625	3
.9375	1	1.0625	1.125	1	3.875	2.75	3.125
1	1	1.125	1.125	1	4.125	2.875	3.25

Lap of Joint or Course should be .5 pitch of rivets added to .3 diam. of rivet.

NOTE.—Lloyd's requires a spacing of 4.5 diameter. Liverpool Registry, 4. Admiralty, 4.5 to 5 in edges and abuts of bottom and bulkhead plates, and 5 to 6 [illegible] other water-tight work. *Bureau Veritas*, 4 diameters for single riveting, and [illegible] for double.

STEEL PLATES.

Steel Plates, according to M. Barba, .354 inch thick are equal to wrought iron .472 inch thick, or as 3 to 4; consequently, when iron rivets are used their diameter should be in proportion to an iron plate.

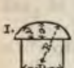
It is ascertained also that they are best united by iron rivets.

A steel plate .3125 inch thick requires an iron rivet .5625 inch in diameter, and 1.375 ins. apart.

Bridge Plates and Rivets.

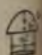
Plates .25 to .5 inch thick. Rivets .75 to 1 inch diameter, and 3 ins. apart from centres in upper flange or girder, and 4 ins. in lower

Rivet Heads.

1. 

Ellipsoidal, Fig. 1.—D *diameter*, R *radius of head* = D, *r radius of flange* = .4 D, *c depth at centre* = .5 D.

Segmental, Fig. 2.—D *diameter*, *c depth at centre* = .625 D, R *radius of head* = .75 D, *o depth below head* = .125 D.



Countersunk.—Head 1.52 D, angle 60°. Countersink .45 diam. of plate.

Cheesehead or heads, section of which is a parallelogram. Head .45 [illegible] diameter 1.5 D.

Rivets.

Shearing strength of a Lowmoor rivet = 40 320 d^2 or 18 d^2 in tons. *d representing diameter of rivet in ins.*

Memoranda.

Punching holes for riveting weakens plates, varying from 10 to 20 per cent. according to their temper, hardest losing most.

Countersunk riveting does not impair strength of joint, as compared with external head.

Diagonal abut joints are stronger than square.

Shearing strength of rivets should not exceed that of plates.

Maximum strength of joint is attained at 90 to 100 per cent. of net section of plate.

Shearing strength of English wrought iron is taken at 80 per cent. of its tensile strength.

LEAD PIPE.

;esistance of Lead Pipe to Internal Pressure.

(*Kirkaldy, Jardine, and Fairbairn.*)

hick-ness.	Weight per Foot.	Bursting Pressure.	Diam.	Thick-ness.	Weight per Foot.	Bursting Pressure.	Diam.	Thick-ness.	Weight per Foot.	Bursting Pressure.
nch.	Lbs.	Lbs.	Ins.	Inch.	Lbs.	Lbs.	Ins.	Inch.	Lbs.	Lbs.
.2	2.3	1579	1.25	.21	5.3	683	2	.21	9.2	498
.2	2.6	1349	1.5	.24	7.1	734	2	.2	—	448
.22	3.8	1191	1.5	.2	—	528	3	.25	—	364
.2	4.1	911	1.5	.2	—	626	3	.25	—	374

le strength of metal = 2240 lbs. per sq. inch.

ompute Thickness of a Lead Pipe when Diameter and Pressure in Lbs. per Sq. Inch is given.

E.—Multiply pressure in lbs. per sq. inch by internal diameter of pipe and divide product by twice tensile resistance of metal in lbs. per sq.

TRATION.—Diameter of a lead pipe is 3 ins., and pressure to which it is to ıitted is 370 lbs. per sq. inch; what should be thickness of metal?

$$\frac{370 \times 3}{2240 \times 2} = \frac{1110}{4480} = .248 \textit{ ins.}$$

'ence in Weight between Pipes of "Common," "Middling," and "Strong" r cent.

To Compute Weight of Lead Pipe.

$\overline{d^2}\,3.86 = W$. D *and d representing external and internal diameters in ins., weight of a lineal foot in lbs.*

ompute Maximum or Bursting Pressure that may be borne by a Lead Pipe.

E.—Multiply tensile resistance of metal in lbs. per sq. inch by twice ɔss of pipe, and divide product by internal diameter, both in ins.

TRATION.—What is bursting pressure of a lead pipe 3 ins. in diameter and thick?

$$\frac{2240 \times \overline{.5 \times 2}}{3} = \frac{2240}{3} = 746.6 \textit{ lbs.}$$

ne a column of water 34 feet in height to weigh 15 lbs. per sq. inch; what water would such a pipe sustain at point of rupture?

15 : 34 :: 746.6 : 1692.3 *feet.*

ɜtance of Glass Globes and Cylinders to Internal Pressure and Collapse. (*Flint Glass.*)

Bursting Pressure.

GLOBES.			CYLINDER.			
ter.	Thickness.	Per Sq. Inch.	Diameter.	Length.	Thickness.	Per Sq. Inch.
	Inch.	Lbs.	Ins.	Ins.	Inch.	Lbs.
	.024	84	4	7	.079	282
	.022	90	Elliptical (Crown Glass).			
	.059	152	4.1	7	.019	109

Collapsing Pressure.

	.014	292	3	14	.014	85
	.025	1000*	4	7	.034	202
	.059	900*	4	14	.064	297

* Unbroken.

Manganese Bronze.

Manganese Bronze, No. 2, has a Tensile strength of 72000 to 78600 lbs. per sq. inch, its elastic limit is from 35000 to 50000 lbs., its ultimate elongation 12 to 22 per cent., and its hardness alike to that of *mild* steel.

Transverse Strength.—Destructive stress of a bar 1 inch square, supported at both ends at a distance of 1 foot = 4200 lbs., bending to a right angle before breaking, and requiring 1700 lbs. to give it a permanent set.

MEMORANDA.

Cast Iron.

Beams cast horizontally are stronger than when cast vertically.

Relative strength of columns of like material and of equal weights is: Cylindrical, 100; Square, 93; Cruciform, 98; Triangular, 110. (*Hodgkinson.*)

If strength of a cylindrical column is 100, one of a square, a side of which is equal to diameter of the cylinder, is as 150.

Repetition of Stress.—A piece submitted to transverse stress broke at 1956th strain, with a stress .75 of that of its original ultimate resistance.

Resistance to Bursting of Thick Cylinders.—Mean resistance to bursting of chambers of cast-iron guns is as follows (*Major Rodman, U.S.A.*):

Thickness of metal = 1 calibre, length = 3 calibres, 52217 *lbs.* per sq. inch.
Thickness of metal = .5 calibre, length = 3 calibres, 49100 *lbs.* per sq. inch.
The tensile strength of the iron being 18820 *lbs.*

Diam. of cylinder 2 ins., length 12 ins., metal 2 ins., 80229 *lbs.* per sq. inch.
Diam. of cylinder 3 ins., length 12 ins., metal 3 ins., 93702 *lbs.* per sq. inch.
Tensile strength of iron being 26866 *lbs.*

Sudden Applications of Stress.—Loss of strength by sudden application of load was, by experiment, 18.6 per cent. in excess of load applied gradually, and its elongation 20 per cent. greater.

Low Temperature.—Tensile strength at 23° under sudden application of load, was reduced 3.6 per cent., and elongation 18 per cent.

Wrought Iron.

Increased Hammering gives 20 per cent. greater strength with decreased elongation.

Hardening.—Water increases strength more than oil or tar. A bar $\frac{5}{8}$ inch in diameter, forged and hardened in water, attained a tensile strength of 73448 lbs. (*Mr. Kirkaldy.*)

Case Hardening.—Loss of tensile strength 4950 lbs. per sq. inch.

Cold Rolling added 18.5 per cent. to tensile strength, and when plates were reduced .33 in thickness, strength was nearly doubled, with but .1 per cent. elongation. Specific gravity was reduced.

Fibre.—Plates are about 12 per cent. stronger with fibre than across it.

Angles, Tees, etc., have from 2200 to 4500 lbs. less tensile strength than ...ctangular bars.

...*vanizing* does not perceptibly affect strength.

...*ing.*—Strength as affected by welding varies by experiment from 2.6 ... per cent. less, average being 19.4.

...is about .45 of its tensile breaking weight, .15 of its com... ...trength, and .5 of its transverse strength.

...*ads.*—1 inch bolts lose by dies 6.11 per cent., and by

Steel.

...ter at a... ...rature of 310°.

WOODS.

pute Transverse Strength of Large Timber.

Destructive Stress.

ne End, and Loaded at the Other. $\frac{.3\, S\, b\, d^2}{l} = W.$

oth Ends, and Loaded in Middle. $\frac{1.8\, S\, b\, d^2}{l} = W.$

l at Both Ends, and Loaded in Middle. $\frac{1.2\, S\, b\, d^2}{l} = W.$

oth Ends, and Loaded at any other point than $\Big\}\ \frac{.45\, S\, b\, d^2}{l} = W.$

at Both Ends, and Loaded at any other point
dle. $\Big\}\ \frac{.3\, S\, b\, d^2\, l}{m\, n} = W.$

* Hence, $\frac{W\, l}{1.2\, b\, d^2} = S$, and $\frac{W\, l}{b\, d^2} = 1.2\, S.$

epresenting breadth, depth, and length to or between supports, all in f tensile and crushing strengths of material at two thirds of its Value, by experiments, W *ultimate weight or stress in lbs., and m and n dis- from nearest supports in ins.*

n is uniformly loaded, the stress is twice that if applied in its middle

Values of 1.2 S.

ther coefficients, as .3, 1.8, etc., the values will be proportional.

Woods.	1.2 S	Woods.	1.2 S
....	2.38	Locust	3.7
....	2.4	Mahogany, Honduras............	2.3
....	2.46	Oak, Pa..................	2
....	2.55	" Va..................	2.3
....	2.5	" white..................	2.5
....	1.6	" English..................	1.7
....	1.6	" Dantzic..................	1.35
....	1.53	" French..................	2.44
....	.85	Pine, Va..................	3
....	1.12	" pitch..................	2.2
ınada..............	2.63	" white..................	2.71
....	2.5	" yellow..................	3.87
....	3.81	" " Canada.............	1.8
....	2	Redwood, Cal..................	1.1
....	1.36	Spruce..................	1.2
....	3.64	Teak..................	3.17
....	1.77	Walnut, black..................	1.25

ɔn 1.—What is destructive stress of a beam of English oak, 2 ins. feet between its supports?

ble $= 1.7$, and S $= .66$ of 5700 (mean of tensile and crushing strength)

$$\frac{1.7 \times 2 \times 2^2 \times 3762}{6 \times 12} = \frac{51\,163}{72} = 710.6\ lbs.$$

ent of Mr. Laslett it was 688 *lbs.*

destructive stress of a beam of yellow pine, 3 ins. by 12, and 14 ıpports?

ıle $= 3.87$, and S $= .66$ of 10 200 (mean of tensile and crushing stre

$$\frac{3.87 \times 3 \times 12^2 \times 6732}{14 \times 12} = \frac{11\,254\,827}{168} = 66\,993\ lbs.$$

was fixed at both ends then 3.87 would be 5.8.

Or, as 1.2 : 1.8 :: 3.87 : 5.8.

Loads for Rectangular Beams of Various Materials, One Inch in Breadth and One Foot in Length. Supported at Both Ends and Loaded in Middle.

African, B *Baltic*, B'k *Black*, C *Canadian*, D *Dantzic*, E *English*, G *Georgia*, M *Memel*, P *Pitch*, R *Riga*, W *White*, Y *Yellow*.—*Figures at Head of Columns denote Destructive Weight of Material in Lbs.*

Depth.	B'k Ash. Red Cedar. 300	C Fir. B'k Spruce. Larch. 320	Birch. Hackmatack. Hemlock. 400	W Beech. Walnut. C Ash. R Fir. 450	Spruce. Sycamore. Elm. W Pine. 500	Beech. Y Pine. E Oak. 525	P Pine. C Oak. Spruce. 550	W Oak. B Fir. 600	M Fir. Chestnut. E Ash 640	Ash. D Fir. Rock Elm. 680	Hickory. Maple. Af Oak. G Pine. 800	Locust. 1180
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	60	64	80	90	100	105	110	120	128	136	160	236
2	240	256	320	360	400	420	440	480	512	544	640	944
3	540	576	720	810	900	945	990	1 080	1 152	1 224	1 440	2 124
4	960	1 024	1 280	1 440	1 600	1 680	1 760	1 920	2 048	2 176	2 560	3 776
5	1 500	1 600	2 000	2 250	2 500	2 625	2 750	3 000	3 200	3 400	4 000	5 900
6	2 160	2 304	2 880	3 240	3 600	3 780	3 960	4 320	4 608	4 896	5 760	8 496
7	2 940	3 136	3 920	4 410	4 900	5 145	5 390	5 880	6 272	6 664	7 840	11 564
8	3 840	4 096	5 120	5 760	6 400	6 720	7 040	7 680	8 192	8 704	10 240	15 104
9	4 860	5 184	6 480	7 290	8 100	8 505	8 910	9 720	10 368	11 016	12 960	19 116
10	6 000	6 400	8 000	9 000	10 000	10 500	11 000	12 000	12 800	13 600	16 000	23 600
11	7 260	7 744	9 680	10 890	12 100	12 605	13 310	14 520	15 488	16 456	19 360	28 556
12	8 640	9 216	11 520	12 960	14 400	15 120	15 840	17 280	18 432	19 584	23 040	33 984
13	10 140	10 816	13 520	15 210	16 900	17 745	18 590	20 280	21 632	22 984	27 040	39 884
14	11 760	12 544	15 680	17 640	19 600	20 580	21 560	23 520	25 088	26 656	31 360	46 256
15	13 500	14 400	18 000	20 250	22 500	23 625	24 750	27 000	28 800	31 600	36 000	53 100
16	15 360	16 384	20 480	23 040	25 600	26 880	28 160	30 720	32 768	34 816	40 960	60 416

Illustrations of Table.

1.—What is safe statical load for a white-pine beam, 4 ins. by 12, and 15 feet between its supports, loaded in middle.

A like beam, 1 inch in width, 12 ins. in depth, and 1 foot between its supports, will bear as per table 14 400 lbs.

2.—What should be depth of a like beam, 3 ins. in width, and 10 feet between its supports, to bear a statical weight of 1920 lbs.?

Coefficient or Safe load for the material = 500 ÷ 5 = 100.

$$\sqrt{\frac{10 \times 1920}{4 \times 100 \times 1}} = \sqrt{\frac{19\,200}{400}} = \sqrt{48} = 6.93 \text{ ins.}$$

To Compute Depth of a Header Beam.

LE.—See rule for depth of a floor beam, page 835, with the exception ı header is assumed to be always uniformly loaded.

$$\text{Or, } \sqrt{\frac{l \cdot .5\ W}{b\ C}} = d.$$

To Compute Breadth of a Trimmer Beam.

'th One Header and One Set of Tail Beams. RULE.—Proceed as for utation of dimension of a beam loaded at any other point than middle.

$\frac{n\ n\ W}{l\ d^2\ C} = b.$ *m and n representing distances of the weight or load from each ı feet.*

USTRATION.—What should be breadth of a trimmer or carriage beam of Georgia 23 feet in length, 15 ins. in depth, sustaining a header 10 feet in length, with eams 19 feet, and designed for a load of 540 lbs. per sq. foot of floor?

ume $C = 100$; $d = 15 - 1 = 14$; *m and n = 19 and 4 feet.*

$$.5 \times \frac{19 \times 4 \times \overline{19 \times 10 \div 2} \times 540}{23 \times 100 \times 14^2} = .5 \times \frac{3\,898\,800}{450\,800} = 4.32 \textit{ ins.}$$

TE 1.—Depth of trimmer beams is usually determined by depth of floor beams; ı not, proceed to determine it as for a header.

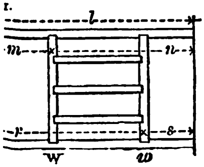
-When a trimmer beam is mortised to receive headers, it is proper to deduct h from its depth, as in preceding illustrations. When bridle or stirrup irons sed to suspend headers, a deduction of the thickness of the iron only is neces- usually .5 inch.

With Two Headers and One Set of Tail Beams.—Fig. 1.

PERATION.—Proceed for each weight or load as for a beam, when weights sustained or stress borne at other point than the middle.

$\frac{a\ L}{4} = W$ and w. *a representing area of floor in sq. feet,* L *load per sq. foot,* W *and w weights or loads at points of rest on trimmers.*

1.



NOTE.—Hatfield and some other authors give complex and extended formulas, to deduce the dimensions of a Girder or Beam, under a like stress.

Upon consideration, however, it will readily be recognized that a beam loaded at more than one point is simply two or more beams, as the case may be, loaded at different points, and connected together.

ILLUSTRATION.—What should be breadth of a trimmer beam of Yellow or Georgia pine, 25 feet in length, 12 ins. in depth, sustaining two headers et in length, set at 15 feet from one wall and 5 feet from the other, to support safety 300 lbs. per sq. foot of floor?

$= 25$, $m = 15$, $n = 10$, $s = 5$, $r = 20$, $C = 100$, and $d = 12 - 1 = 11$ *fo by mortising.*

$\frac{\times 5 \times 300}{4} = \frac{18\,000}{4} = 4500$ *lbs. at* W, and $\frac{12 \times 5 \times 300}{4} = \frac{18\,000}{4} = 4500$ *lbs. at*

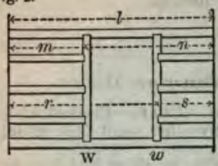
ien $\frac{15 \times 10 \times 4500}{25 \times 11^2 \times 100} = \frac{675\,000}{302\,500} = 2.23$ *ins. breadth for load on header at 15 ft*

$\frac{5 \times 20 \times 4500}{25 \times 11^2 \times 100} = \frac{450\,000}{302\,500} = 1.48$ *ins. breadth for load on header at 5 feet,* and

$+ 1.48 = 3.71$ *ins. combined breadth.*

With Two Headers and Two Sets of Tail Beams.—Fig. 2.

Fig. 2.



OPERATION.—Proceed as directed for Fig. 1.

ILLUSTRATION.—What should be breadth of trimmer beam of yellow pine 25 feet in length, 15 ins. in depth, sustaining two headers 12 feet in length, set at 15 feet from one wall and 5 feet from the other, to support with safety 300 lbs. per sq. foot of floor?

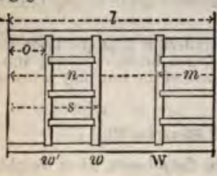
$l=25,\ m=15,\ n=10,\ s=5,\ r=20,\ C=100$, and $d=15-1=14$ *for loss by mortising.*

$\frac{12\times15\times300}{4}=\frac{54\,000}{4}=13\,500$ *lbs.* at W, and $\frac{12\times5\times300}{4}=\frac{18\,000}{4}=4500$ *lbs.* at *w.*

Then $\frac{15\times10\times13\,500}{25\times14^2\times100}=\frac{2\,025\,000}{490\,000}=4.14$ *ins.*, and $\frac{5\times20\times4500}{25\times14^2\times100}=\frac{450\,000}{490\,000}=.92$ *ins.*, and $4.14+.92=5.06$ *ins. combined oreadth.*

With Three Headers and Two Sets of Tail Beams.—Fig. 3.

Fig. 3.



OPERATION.—Proceed as directed for Fig. 1.

ILLUSTRATION.—What should be breadth of trimmer beam of yellow pine, 20 feet in length, 13 ins. in depth, sustaining 3 headers 15 feet in length, set at 3, 7, and 13 feet from one wall, to sustain a load of 200 lbs. per sq. foot of floor?

$l=20,\ m=7,\ n=13,\ s=7,\ o=3,\ d=13-1=12$ *ins.*, and $C=100$.

$\frac{15\times7\times200}{4}=\frac{21\,000}{4}=5250$ *lbs. at* W;

$\frac{15\times\overline{7-3}\times200}{4}=\frac{12\,000}{4}=3000$ *lbs. at w*; and $\frac{15\times\overline{7-3}\times200}{4}=3000$ *lbs. at w'.*

Then $\frac{7\times13\times5250}{20\times12^2\times100}=\frac{477\,750}{288\,000}=1.66$ *ins.*; $\frac{7\times13\times3000}{20\times12^2\times100}=\frac{273\,000}{288\,000}=.95$ *ins.*; and $\frac{3\times17\times3000}{20\times12^2\times100}=\frac{153\,000}{288\,000}=.53$ *ins.* Hence, $1.66+.95+.53=3.14$ *ins. combined breadth.*

Stirrups or Bridles.

Stirrups are resorted to in flooring designed for heavy loads, in order to avoid the weakening of the trimmers by mortising.

Average wrought iron will sustain from 40 000 to 50 000 lbs. per sq. inch.

Hence 45 000 lbs. as a mean, which ÷ 5 for a factor of safety, = 9000 lbs.

A stirrup supports one half weight of header, and being doubled (looped) the stress on it is but $.5\div2=.25$ of load on header.

To Compute Dimensions of Stirrups or Bridles.

$$\frac{W\div2}{2\times9000}=\textit{area}.\quad\text{Hence}\ \frac{\text{area}}{\text{thickness}}=\textit{width}.$$

ILLUSTRATION.—What should be area and width of .75 inch wrought-iron stirrup irons for a weight on a header beam of 240 000 lbs.?

$$\frac{240\,000\div2}{2\times9000}=\frac{120\,000}{18\,000}=6.66\text{ sq. ins., and }\frac{6.66}{.75}=8.8\text{ ins.}=\text{width.}$$

Girder.

Condition of stress borne by a Girder is that of a beam fixed or supported both ends, as the case may be, supporting weight borne by all beams ting thereon, at the points at which they rest.

To Compute Dimensions of a Girder.

Rule.—Multiply length in feet by weight to be borne in lbs., divide oduct by twice* the *Coefficient*, and quotient will give product of breadth d square of depth in ins.

$$\text{Or, } \frac{l\,W}{2\,C} = b \text{ and } d^2, \text{ and } \sqrt{\frac{l\,W}{2\,b\,C}} = d.$$

Example.—It is required to determine dimensions of a yellow-pine girder, 15 feet ween its supports, to sustain ends of two lengths of beams, each resting upon it l adjoining walls, 15 feet in length, having a superincumbent weight, including .t of beams, of 200 lbs. per sq. foot.

Condition of stress upon such a girder is that of a number of beams, 30 feet in gth (15 × 2), supported at their ends, and sustaining a uniform stress along their gth, of 200 lbs. upon every superficial foot of their area.

Coefficient .2 of 500 = 100.

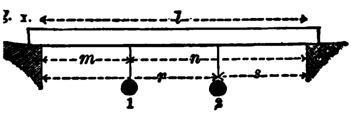
$$30 \times 15 \times 200 \div 2, \textit{ for half support on their walls} = 45\,000 \textit{ lbs.}$$

Then $\frac{15 \times 45\,000}{2 \times 100} = 3375 = b$ and d^2. Assuming $b = 12$ *ins.*, then $\sqrt{\frac{3375}{12}} = 16.77$ s. Or, if 15 ins., then $\sqrt{\frac{3375}{15}} = 15$ *ins.*

To Compute Greatest Load upon a Girder, and Dimensions thereof.—Fig. 1.

When a Beam is Loaded at Two Points.

Fig. 1.



$\frac{m\,n}{l}$ = *effect of weight at* 1,

$\frac{r\,s}{l}$ = *effect of weight at* 2,

$\frac{m}{l}(W \times n + w\,s)$ = *the two effects* 1, and $\frac{s}{l}(w\,r + W\,m)$ = *two effects at* 2.

Then, for weight and dimensions, same formulas will apply.

Illustration.—Assume weight of 8000 lbs. at 3 feet from one end of a white-pine am 12 feet in length between its bearings, and another weight of 3000 lbs. at 5 t from other end. C .2 of 500 = 100.

$8000 \times 3 \times \overline{12 - 3} = 216\,000$ *effect of weight at location* 1, and $3000 \times 5 \times \overline{12 - 5}$ 105 000 *effect of weight at location* 2. Hence 1, being greatest, = W, and 2 = w.

$$\text{Then, } \frac{3 \times 9}{12} \times 8000 = 18\,000 \text{ at W, and } \frac{5 \times 7}{12} \times 3000 = 8750 \text{ at } w; \text{ and}$$

$\overline{(8000 \times 9} + \overline{3000 \times 5)} = 21\,750$ = *total effect at* W, and $\frac{5}{12}\,(\overline{3000 \times 7} + \overline{8000 \times 3})$ 18 750 = *total effect at* w.

Hence, to ascertain dimensions at greatest stress,

$\frac{21\,750 \times 3 \times 9}{12 \times 300} = 163.12$, and assume $d = 10$, then $\frac{163.12}{10^2} = 1.63$ *ins. breadth;* $\sqrt{\frac{163.12}{1.63}} = 10$ *ins. depth.*

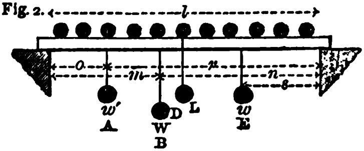
* For being uniformly loaded.

Verification.—Assume a beam as above loaded with 21 750 lbs. at 3 feet from end

Then, by formula for 801, $\frac{3 \times 9 \times 21\,750}{12 \times 10^2 \times 100} = \frac{587\,250}{120\,000} = 4.89$ *ins.*

Equivalent Weight at Middle.—Fig. 2.

Fig. 2.



$\frac{w' o}{l \div 2} = A$; $\frac{W n}{l \div 2} = B$; $\frac{w s}{l \div s} = E$; and $\frac{L l}{l} \div 2^* = D =$ *equivalent load at middle.*

ILLUSTRATION.—What should be breadth of a beam of Georgia pine, 20 feet in length, 15 ins. in depth, uniformly loaded with 4000 lbs., and sustaining 3 headers or concentrated loads of 6000 lbs., at respective distances of 4 and 9 feet from one end and 7000 lbs. at 6 feet from other end?

$o = 4$, $r = 16$, $m = 9$, $n = 11$, $s = 6$, $d = 15 - 1 = 14$, $L = 4000$, and $C = 850 \times .2 = 170$. $\frac{6000 \times 4}{20 \div 2} = 2400$; $\frac{6000 \times 9}{20 \div 2} = 5400$; $\frac{7000 \times 6}{20 \div 2} = 4200$;

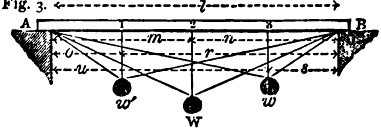
and $\frac{4000 \times 20}{20} \div 2 = 2000$. $2400 + 5400 + 4200 + 2000 = 14\,000$ *lbs.*

Then $\frac{14\,000 \times 10 \times 10}{20} = 70\,000$ *lbs., effect at middle.*

Hence, $\frac{20 \times 70\,000}{4 \times 14^2 \times 170} = \frac{1\,400\,000}{133\,280} = 10.5+$ *ins.*

Operation deduced by Graphic Delineation of Greatest Stress without uniform Load.

Fig. 3.



Moments of weights $= \frac{w' o r}{l}$; $\frac{W m n}{l}$; and $\frac{w s u}{l} =$ 19 200, 29 700, and 29 400, and let fall perpendiculars 1, 2, and 3 proportionate thereto.

Connect w', W, and w with A B, and sum of distances of intersections of these lines upon perpendiculars, from 1, 2, and 3, respectively, will give stress upon A B at these points.

Whence, greatest stress at greatest load will be ascertained to be 61 800 lbs.

When Loaded at Three Points, as in Fig. 2. $\frac{m}{l}(W n + w s) + w' \frac{n o}{l} =$ *Greatest Stress.*

ILLUSTRATION.—Take elements of above case, omitting uniformly distributed load.

$\frac{9}{20}(6000 \times 11 \times 7000 \times 6) + 6000 \frac{11 \times 4}{20} = \frac{9}{20} \times 108\,000 + 13\,200 = 61\,800$ *lbs.*

Deflection of Girders and Beams.

$\frac{W l^3}{} = D$; $\frac{C b d^3}{l^3} = W$; $\sqrt[3]{\frac{W l^3}{C b D}} = d$; and $\sqrt[3]{\frac{C b d^3 D}{W}} = l$. *l represent* *feet, b and d breadth and depth, and* D *deflection in ins.*

Values of C *for Various Woods.* (*Hatfield.*)

... 4000	Larch............... 2093	Pine, Georgia........ 5900
.. 2550	Oak, white.......... 3100	" pitch.......... 2836
. 2800	" English, mean.. 2686	" white.......... 2900
3850	Spruce.............. 3500	" red............ 4259

...ould be deflection of a floor beam of white pine, 10 feet ...d 8 in depth, with 4000 lbs. loaded in its middle?

$\ldots \times \frac{10^3}{\ldots} = \frac{4\,000\,000}{\ldots 939\,200} = .674$ *inch.*

...nted.

When Weight is Uniformly Distributed.

$$\frac{.625\ W\ l^3}{C\ b\ d^3}=D;\quad \frac{C\ b\ d^3}{.625\ l^3}=W;\quad \sqrt[3]{\frac{C\ b\ d^3\ D}{.625\ W}}=l;\ \text{and}\ \sqrt[3]{\frac{W\ .625\ l^3}{C\ b}}=d.$$

[H]ence, Deflection in preceding illustration would be $.674 \times .625 = .421$ *ins.*

[I]LLUSTRATION.—What should be length of a white-pine beam 3 by 10 ins., to sup[po]rt 6000 lbs. uniformly distributed, with a deflection of 2 ins.? $C = 2900$.

$$\sqrt[3]{\frac{2900 \times 3 \times 10^3 \times 2}{.625 \times 6000}}=\sqrt[3]{\frac{17\,400\,000}{3750}}=16.68\ \textit{feet.}$$

A fair allowance for deflection of floor beams, etc., is .03 inch per foot of length; [.]. inch may be safely resorted to.

Weights of Floors and of Loads.

Dwellings.—Weight of ordinary floor plank of white pine or spruce, 3 lbs. [pe]r sq. foot, and of Georgia pine, 4.5 lbs.

Plastering, Lathing, and Furring will average 9 lbs. per sq. foot.

Clay Blocks (*Flat Arch*) 5.25×7.25 ins. in depth and 1 foot in length, lbs. = 80 lbs. per cube foot of volume.

Floors of dwellings will average 5 lbs. per sq. foot for white pine or spruce, [an]d on iron girders will average from 17 to 20 lbs. per sq. foot.

Weight of men, women, and children over 5 years of age, 105.5 lbs., and [on]e third of each will occupy an average area of 12×16 ins. = 192 sq. ins. 78.5 lbs. per sq. foot.

Of men alone 15×20 ins. = 300 sq. ins. = 48 in 100 sq. feet.

Bridges, etc.—Weight of a body of men, as of infantry closely packed, = [..]5 lbs. each, and they will occupy an area of 20×15 ins. = 300 sq. ins. = [.]24 lbs. per sq. foot of floor of bridge, and as a live or walking load, 80 lbs. [pe]r sq. foot.

Weight of a dense and stationary crowd of men, 120 lbs. per sq. foot.

Bridging of *Floor Beams* increases their resistance to deflection in a very [es]sential degree, depending upon the rigidity and frequency of the bridges.

[W]eight on Floors, etc., in addition to Weight of Structure, per Sq. Foot.

[Ba]ll rooms	85 lbs.	Roofs, wind and snow	30 to 35 lbs.
[Bri]ck or stone walls	115 to 150 "	Slate roofs	45 "
[Ch]urches and Theatres	80 "	Snow, per inch	.5 lb.
[Dw]ellings	40 "	Street bridges	80 lbs.
[Fac]tories	200 to 400 "	Warehouses	250 to 500 "
[Gra]in	100 "	Wind	50 "

Scarfs.

Relative resistance of scarfs in Oak and Pine, 2 ins. square, and 4 feet in [len]gth, by experiments of Col. Beaufoy.

Scarf 12 ins. in Length and 13 ins. from End, or 1 inch from Fulcrum.

Vertical.—110 lbs. gave away in scarf.

Horizontal, large end uppermost and towards fulcrum.—101 lbs. fastenings [dr]ew through small end of scarf; *small end uppermost, etc.*, 87 lbs. gave [aw]ay in thick part of scarf.

Factors of Safety.

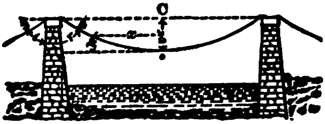
Statical or Dead Load at .2 of destructive stress, but for ordinary pur[po]ses it may be increased to .25, and in some cases with good materials to .3.

Live Load at .1 to .125 of destructive stress.

See also page 802.

SUSPENSION BRIDGE.

To Compute Elements.



$$\frac{C\,L}{8\,v} \text{ or } \frac{Q\,a^2}{2\,v} = S; \qquad \frac{v\,x^2}{(.5\,C)^2} = h;$$

$$S\sqrt{\left(\frac{2\,h}{x}\right)^2 + 1} = s = S \text{ sec. } o;$$

$$\frac{4\,h}{2\,x} = \text{tan. angle } o; \qquad \frac{L}{n-1} = t';$$

$$2\sqrt{(.5\,C)^2 + \frac{4}{3}\,v^2} = l; \qquad \frac{4\,v}{C} = \text{cot. } r; \qquad \frac{C\,L}{8\,S} = v; \qquad \frac{8\,v\,t}{C}\sqrt{\left(\frac{4\,v}{C}\right)^2 + 1} = L;$$

$$S \div \sqrt{\left(\frac{4\,v}{C}\right)^2 + 1} = t; \text{ or } \frac{L \div 2}{s} = t; \qquad \frac{2\,v}{\sqrt{(2\,v)^2 + (C \div 2)^2}} = s, \text{ and } \frac{L \div 2 \times \text{cos}}{\text{sin. } s}$$

= stress at *o*. C *representing chord or span, a half chord, and v versed sine of chord or curve of deflection, in feet,* L *distributed load inclusive of suspended structure,* Q *load per lineal foot, and* S *stress at centre, all in tons, x distance of any point from centre of curve, and h height of chain at x above centre of it, both in feet, stress on chain at any point, as x, from centre of span, s stress on any tension-rod, and t stress at abutments, all in tons, n number of tension-rods, o angle of tangent of chain with horizon at any point, as x, r angle of chain with vertical at abutments, l length of chain, in feet, and s angle of direction of chain.*

Assume C = 300 *feet*, L = 1000 *tons*, v = 25 *feet*, x = 100 *feet*, n = 30, r = 71° 34′, and o = 12° 32′.

$$\text{Then, } \frac{300 \times 1000}{8 \times 25} = 1500 \text{ tons} = S; \qquad \frac{25 \times 100^2}{(.5 \times 300)^2} = 11.11 \text{ feet} = h;$$

$$1500\sqrt{\left(\frac{2 \times 11.11}{100}\right)^2 + 1} = 1536.56 \text{ tons} = s; \qquad \frac{4 \times 11.11}{2 \times 100} = .2222 = 12^\circ\,32' = \text{tan.} \angle\, o;$$

$$2\sqrt{(.5 \times 300)^2 + \frac{4}{3}\,25^2} = 305.5 \text{ feet} = l; \qquad \frac{300 \times 1000}{8 \times 1500} = 25 = v;$$

$$\frac{4 \times 25}{300} = .3333 = 71^\circ\,34' = \text{cot. angle } r; \qquad \frac{1000}{30-1} = 34.48 \text{ tons} = t';$$

$$\frac{1500}{\sqrt{\left(\frac{4 \times 25}{300}\right)^2 + 1}} = 1423.1 \text{ tons} = t; \text{ and } \frac{2 \times 25}{\sqrt{(2 \times 25)^2 + (300 \div 2)^2}} = .3162 = 18^\circ\,26'.$$

For a deflection of .125 of span, horizontal stress is equal to total load.

To Construct curve, see Geometry, page 230.

To Compute Ratio which Stress on Chains or Cables at either Point of Suspension Bears to whole Suspended Weight of Structure and Load.

$$\frac{1}{2 \times \text{sin. } s} = R. \quad R \text{ representing ratio.}$$

ILLUSTRATION.—Assume elements of preceding case.

$$\frac{1}{2 \times .3162} = 1.58 \text{ ratio.}$$ By a preceding formula it would be 1.536.

Stress on Back Stays.—The cables being led over rollers, having free motion, tension upon them is same, whether angle i is same as that of r or not.

Stress on Piers.—When angles r and i are alike, stress on piers will be vertical, but when angle of i is greater or less than r, stress will be oblique.

Compute Horizontal Stress and Vertical Pressure on Piers.

S cos. n = S o, S sin. s = P i, and S sin. n = P o. S i and S o ...ss, *and* P i *and* P o *pressure, inward and outward.*

...f New York and Brooklyn Bridge 1595.5 feet, deflection 128 feet, ...n at piers from horizontal 15° 10′.

TRACTION.

Results of Experiments on Traction of Roads and Pavements. (*M. Morin.*)

1st. Traction is directly proportional to load, and inversely proportional diameter of wheel.

2d. Upon a paved or Macadamized road resistance is independent of dth of tire, when it exceeds from 3 to 4 ins.

3d. At a walking pace traction is same, under same circumstances, for riages with or without springs.

4th. Upon hard Macadamized, and upon paved roads, traction increases h velocity: increments of traction being directly proportional to incrents of velocity above velocity of 3.28 feet per second, or about 2.25 miles hour. The equal increment of traction thus due to each equal increment velocity is less as road is more smooth, and carriage less rigid or better ng.

5th. Upon soft roads of earth, sand, or turf, or roads thickly gravelled, ction is independent of velocity.

6th. Upon a well-made and compact pavement of dressed stones, traction a walking pace is not more than .75 of that upon best Macadamized ads under similar circumstances; at a trotting pace it is equal to it.

7th. Destruction of a road is in all cases greater as diameters of wheels e less, and it is greater in carriages without springs than with them.

Experiments made with the carriage of a *siege train* on a solid gravel ad and on a good sand road gave following deductions:

1. That at a walk traction on a good sand road is less than that on a good rm gravel road.

2. That at high speeds traction on a good sand road increases very rapidly ith velocity.

Thus, a vehicle without springs, on a good sand road, gave a traction 2.64† nes greater than with a similar vehicle on same road with springs.

Results with a Dynamometer.

*Wagon and Load 2240 lbs.**

Roadway.	Relat'e number of horses for like effect.	Roadway.	Relat'e number of horses for like effect.
railway, 8 lbs.	1	Telford road, 46 lbs.	5.75
best stone tracks, 12.5 lbs.	1.56	Broken stone or con'te, 46 lbs.	5.75
od plank road, 32 to 50 lbs.	4 to 6.25	Gravel or earth, 140–147 lbs.	17.5 / 18.37
one block pavement, 32.5 "	4.06		
acadamized road, 65 lbs.	8.12	Common earth road, 200 lbs.	25

NOTE.—By recent experiments of M. Dupuit, he deduced that traction is inversely roportional to square root of diameter of wheel.

Relation of force or draught to weight of vehicle and load over 6 different constructions of road, gave for different speeds as follows:

	Walk.	Trot.		Walk.	Trot.
tage coach, 5 tons	1.3	1	Carriage, seats only, on springs	1.29	1

Resistance to Traction on Common Roads.

On Macadamized or Uniform Surfaces. (*M.*

1. Resistance is directly proportional to pressure.
2. It is independent of width of tire.
3. It is inversely as square root of diameter of wheel.
4. It is independent of speed.

* *See Treatise on Roads, Streets, and Pavements, by Brev. Maj.-Gen'l* (

† Telford estimated it at 3.5.

On Paved and Rough Roads.

Resistance increases with speed, and is diminished by an enlargement of tire up to a moderate limit.

***Traction on Various Roads.*—Traction of a wheeled vehicle is to its weight upon various roads as follows:**

	Per Ton.	Per 100 lbs.		Per Ton.	Per 100 lbs.
Stone track, best	12.5 to 15	.55 to .58	Telford road....	46 to 78	2.1 to 3.5
" "	28 to 39	1.25 to 1.3	Macadamized...	46 to 90	2 to 4
" pavement.	14 to 36	.5 to 1.5	" loose	67 to 112	3 to 5
Asphalted.......	22 to 28	1 to 1.25	Gravel.........	134 to 180	6 to 8
Plank..........	22 to 45	.98 to 2	Sandy..........	140 to 313	6.3 to 14
Block stone pavement....	32 to 35	1.4 to 1.6	Earth..........	200 to 290	9 to 13

Hence, a horse that can draw 140 lbs. at a walk, can draw upon a gravel road

$$140 \div \frac{6+8}{2} \times 100 = 2000 \textit{ lbs.}$$

Resistance on Common Roads or Fields.

(*Bedford Experiments*, 1874.*)

GRAVELLED ROAD. (*Hard and dry, rising 1 in 430.*)	Maximum Draft.	Average Draft.	Average Speed per Hour.	HP developed per Minute.	Draft per Ton on Level.	Work per HP per Horse.
	Lbs.	Lbs.	Miles.	HP.	Lbs.	HP.
2 horse wagon without springs.	320	159	2.5	1.06	43.5 or .0192	.53
4 " " " "	400	251	2.6	1.74	44.5 " .02	.87
2 " " with "	300	133	2.47	.88	34.7 " .015	.44
1 " cart without "	180	49.4	2.65	.35	28 " .0125	.35
ARABLE FIELD. (*Hard and dry, rising 1 in 1000.*)						
2 horse wagon without springs.	1000	700	2.35	4.36	210 or .099	2.18
4 " " " "	1200	997	2.52	6.7	194 " .083	3.35
2 " " with "	1000	710	2.35	4.45	210 " .099	1.22
1 " cart without "	400	212	2.61	1.48	140 " .0625	1.48

Fore wheels of wagons were 39 ins., and hind 57 ins. in diam.; tires varying from 2.25 to 4 ins.; and wheels of cart were 54 ins. in diam., and tires 3.5 and 4 ins.

Springs reduced resistance on road 20 per cent., but did not lessen it in the field.

From these data it appears, that on a hard road, resistance is only from .25 to .16 of resistance in field. Lowest resistance is that of cart on road = 28 lbs. per ton; due, no doubt, to absence of small wheels alike to those of the wagons.

Assuming average power without springs to be .6 HP on road, as average for a day's work, it represents $.6 \times 33000 = 19800$ foot-lbs. per minute for power of a horse on such a road.

Resistance of a smooth and well-laid granite track (tramway), alike to those in London and on Commercial Road, is from 12.5 to 13 lbs. per ton.

Omnibus.† (*Weight* 5758 *lbs.*)

	Average Speed per Hour.	Per Ton.	Total.
Granite pavement (courses 3 to 4 ins.)........	2.87 miles.	17.41 lbs.	44.75 lbs.
Asphalt roadway...........................	3.56 "	27.14 "	69.75 "
Wood pavement............................	3.34 "	41.6 "	106.88 "
Macadam road, gravelly.....................	3.45 "	44.48 "	114.32 "
" ...nite, new.................	3.51 "	101.09 "	259.8 "

...ce noted for an asphalt roadway is apparently inconsistent ...e pavement, for when it is properly constructed it is least ...ts.

* ... July 10, 1874, page 23. † Report Soc. Arts, London, 1875.

Wagon. (*Sir John Macneil.*)

Weight 2342 *lbs.* *Speed* 2.5 *Miles per Hour.*

	Resistance. Per Ton.	Total.
ıade stone pavement..................................	31.2 lbs.	33 lbs.
ɔade with 6 ins. of broken hard stone, on a foundation ɔnes in pavement, or upon a bottom of concrete......	44 "	46 "
ıt road, or a road made with a thick coating of broken ɔ, on earth..	62 "	65 "
ɔade with a thick coating of gravel, on earth...........	140 "	147 "

Stage Coach. (*Sir John Macneil.*)

Weight 3192 *lbs.* *Gradients* 1 *to* 20 *to* 600.

Speed.	Metalled Road.
6 miles per hour..................................	62 lbs. per ton.
8 " "	73 " "
10 " "	79 " "

—It was found that, from some unexplained cause, the net frictional resistance at equal speeds onsiderably, according to gradient, resistances being a maximum for steepest gradient, and a n for gradients of 1 in 30 to 1 in 40; for these they are less than 1 in 600. Mode of action of es on the carriage may have been an influential element. (*D. K. Clark.*)

ɔompute Resistance to Traction on Various Roads.

(*Sir John Macneil.*)

ON A LEVEL.

ɪᴇ.—Divide weight of vehicle and load in lbs. by its unit in following and to quotient add .025 of load; add sum to product of velocity of e in feet per second, and *Coefficient* in following table for the particular ɪnd result will give power required in lbs.

$\frac{V+w}{unit}+\overline{w\ .025}+\overline{C\,v}=T.$ W *and w representing weights of vehicle and load.*

Coefficients for Traction of Various Vehicles.

ɔoach......................	100	2 horse wagon without springs......	54
wagon.....................	93	2 " " with "	42
ı wagon without springs.....	55	1 " cart without "	36

Coefficients for Roads of Various Construction.

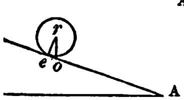
ent.........................	2	Macadamized road................	4.3
ı stone, dry and clean........	5	Gravel, clean.....................	13
" covered with dust....	8	" muddy...................	32
" muddy	10	Stone tramway...................	1.2
Sand and Gravel.......... 12.1			

ɜᴛʀᴀᴛɪᴏɴ.—What is the traction or resistance of a stage coach weighing 2200 ıth a load of 1600 lbs., when driven at a velocity of 9 feet per second over a d clean broken stone road?

$$\frac{2200+1600}{100}+\overline{1600\times .025}+\overline{5\times 9}=123\ lbs.$$

ompute Power necessary to Sustain a Vehicle upon ı Inclined Road, and also its Pressure thereon, omitɪg Effect of Friction.

AT AN INCLINATION.



W : A C :: o : B C, an ::: p : A B.

Or, r e : e o :: A B : B(: h: whence,

$W\,\frac{h}{l}=e\,o.$

Assume A B of such a rise, 1 foot; then,

$=\frac{W}{\sqrt{AB^2+1}}=W\sin.A=o,$ and $\frac{W\,A\,B}{A\,C}=\frac{W\,A}{\sqrt{AB^2}}$

To Compute Frictional Resistance to Traction of Stage Coach on a Metalled Road in Good Condition

$30 + 4v + \sqrt{10v} = R$. *v representing speed in miles per hour, and* R *frictio resistance to traction per ton.*

NOTE.—Formula is applicable to wagons at low speeds.

Canal, Slackwater, and River.

On a canal and water, resistance to traction varies as square of veloci from that of 2 feet per second to that of 11.5 feet.

When velocity is less than .33 miles per hour, resistance varies in a l degree.

In towing, velocity is ordinarily 1 to 2.5 miles per hour.

Resistance of a boat in a canal depends very much upon the comparati areas of transverse sections of it and boat, it being reduced as differen increases.

In a mixed navigation of canal and slack-water, 3 horses or strong mu will tow a full-built, rough-bottomed canal boat, with an immersed sectio area of 94.5 sq. feet, and a displacement of 240 tons, 1.75 to 2 miles per ho for periods of 12 hours.

With a section of but 24.5 sq. feet, or a displacement of 65 tons, an ave age speed of 2.5 miles is attained for a like period.

By the observations of Mr. J. F. Smith, Engineer of the Schuylkill Navigatio Co., a canal boat, with an immersed section alike to that above given, can be tow for 10 hours per day as follows:

Per Hour.

By 1 horse or mule.	By 2 horses or mules.	By 3 horses or mules.	By 4 horses or mules.	By 8 horses or mules.
1 mile.	1.5 miles.	1.75 miles.	1.875 miles.	2.5 miles.

Assuming then, the tractive power of a horse as given in table, page 437, the abov elements determine results as follows:

Horses.	Miles.	Tractive Power divided by Load.	Traction in Lbs. per Ton.	Traction in Lbs. per Sq. Foot of immersed Section.
1	1	$250 \div 240$	1.04	2.65
2	1.5	$165 \times 2 \div 240$	1.38	3.49
3	1.75	$140 \times 3 \div 240$	1.75	4.44
3	1.875	$132 \times 3 \div 240$	1.65	4.19
3	2	$125 \times 3 \div 240$	1.56	3.98
3 (light)	2.5	$100 \times 3 \div 65$	4.61	12.24

Upon a canal of less section and depth, a displacement of 105 tons, with an im mersed section of 43 sq. feet, a speed of 2 miles with 2 horses was readily obtained which would give a traction of 2.38 lbs. per ton, and of 5.71 lbs. per sq. foot of im mersed section.

Maximum Power of a Horse on a Canal. (*Molesworth.*)

...s per hour	2.5	3	3.5	4	5	6	7	8	9	10
...tion of work in	11.5	8	5.9	4.5	2.9	2	1.5	1.125	.9	.7
...rawn in tons . .	520	243	153	102	52	30	19	13	9	6.5

...eet Railroads or Tramways. (*Gen'l Gillmore.**)

. and at a speed of 5 miles per hour, the power required to draw from $\frac{1}{280}$ to $\frac{1}{350}$ of total weight, varying with condition o ...oisture of their surface.

* Roads, Streets, and Pavements. D. Van Nostrand, 1876, N. Y.

To Compute Resistance of a Car.

f; $\frac{T \times v}{3} = c$; $\frac{v^2 \times a}{400} = r$; and $f + c + r = R$. T *representing weight*
riction in lbs., v *speed in miles per hour*, a *area of front or section of car*
c *concussion*, r *resistance of atmosphere, and* R *total resistance, all in lbs.*

ITION.—Assume a car and load of 8960 lbs., with an area of section of 56 d a speed of 5 miles per hour.

$\frac{60}{40} = 4$ *tons*; $4 \times 6 = 24$ *lbs. friction*; $\frac{4 \times 5}{3} = 6.66$ *lbs. concussion*;

3.5 *lbs. resistance of air*; and $24 + 6.66 + 3.5 = 34.16$ *lbs.*

ge condition of a road, the resistance of a car may be taken at $\frac{1}{120}$, which, ng case, would be 74.66 lbs. On a descending grade, therefore, of 1 in application of a brake would not be required.

WATER.

WATER. Constitution of it by weight and measure is

	By Weight.	By Measure.		By Weight.	By Measure.
gen...	88.9	1	Hydrogen..	11.1	2

nch of distilled water at its maximum density of 39.1°, barom-) ins., weighs 252.879 grains, and it is 772.708 times heavier ospheric air.

oot (at 39.1°) weighs 998.8 ounces, or 62.425 lbs.

–For facility of computation, weight of a cube foot of water is ken at 1000 ounces and 62.5 lbs.

emperature of 32° it weighs 62.418 lbs., at 62° (standard tem- 62.355 lbs., and at 212° 59.64 lbs. Below 39.1° its density , at first very slow, but progressing rapidly to point of conge- ight of a cube foot of ice being but 57.5 lbs.

ght as compared with sea-water is nearly as 39 to 40.

nds .085 53 its volume in freezing. From 40° to 12° it ex- 02 36 its volume, and from 40° to 212° it expands .0467— 000 271 5 for each degree, giving an increase in volume of 1 in 21.41 feet.

Volumes of Pure Water.

7.684 cube ins. = 1 cube foot.	At 62°	1 Ton	= 35.923	cube	feet.
7.68 " " = 1 " "	" "	1 Lb.	= 27.71	"	ins.
7.712 " " = 1 " "	" 39.1°	1 Tonneau	= 35.3156	"	feet.
8.978 " " = 1 " "	" "	1 Kilogr.	= .0353	"	"

Height of a Column of Water at 62° or 62.355 lbs.

sq. inch = 2.3093 feet, and at pressure of atmosphere = 33.947 feet = ers.

Ice and Snow

oot of Ice at 32° weighs 57.5 ll a volume of be ins.

of water at 32°, compared with ic 5 53, ex- eing 8.553 per cent.

ot of new fallen snow weighs 5.2 lb ; of

Rainfall.

Annual Fall at different Places.

Locality.	Ins.	Locality.	Ins.	Locality.	Ins.
Alabama	[illegible]	Ft. Crawford, Wis.	[illegible]	Michigan	[illegible]
Albany	[illegible]	Ft. Gibson, Ark.	[illegible]	Mississippi	[illegible]
Algiers	[illegible]	Ft. Snelling, Iowa	[illegible]	Mobile, Ala.	[illegible]
Allegheny	[illegible]	Fort Monroe, Va.	[illegible]	Naples	[illegible]
Antigua	[illegible]	Florence	[illegible]	Newburg	[illegible]
Archangel	[illegible]	Frankfort on Oder	[illegible]	New York	[illegible]
Athens	[illegible]	Frankfort on Main	[illegible]	Ohio	[illegible]
Bahamas	[illegible]	Geneva	[illegible]	Pacific	[illegible]
Baltimore	[illegible]	Gibraltar	[illegible]	Paris	[illegible]
Barbadoes	[illegible]	Glasgow	[illegible]	Philadelphia	[illegible]
Bath, Me.	[illegible]		32	Plymouth, Eng.	[illegible]
Belfast	[illegible]	Gordon Castle, Sc.	[illegible]	Port Philip	[illegible]
Bergen	[illegible]	Granada	[illegible]	Poughkeepsie	[illegible]
Bombay	[illegible]		[illegible]	Providence	[illegible]
Bordeaux	[illegible]	Great Britain	[illegible]	Rochester	[illegible]
Boston	[illegible]	Greenwich	[illegible]	Rome	[illegible]
Brussels	[illegible]	Halifax	33	Santa Fe	[illegible]
Buffalo	[illegible]	Hanover	[illegible]	Savannah	[illegible]
Burlington, Vt.	[illegible]	Havana	[illegible]	Schenectady	[illegible]
Calcutta	[illegible]	Hong Kong	[illegible]	Sitka	[illegible]
Cape St. Francis	[illegible]	Hudson	[illegible]	Sierra Leone	[illegible]
Cape Town	[illegible]	India	[illegible]	Sitka	[illegible]
Charleston	[illegible]		[illegible]	St. Bernard	[illegible]
Cherbourg	[illegible]	Jamaica	[illegible]	St. Domingo	[illegible]
Cologne	[illegible]	Jerusalem	[illegible]	St. Petersburg	[illegible]
Copenhagen	[illegible]	Key West	[illegible]	State of N.Y.	[illegible]
Cracow	[illegible]	Khassya, India	[illegible]	Sydney	[illegible]
Demerara	[illegible]	Lewiston	[illegible]	Tasmania	[illegible]
[illegible]	[illegible]	Liverpool	[illegible]	Trieste	[illegible]
Dover, Eng.	[illegible]	London	[illegible]	Ultra Mullay, India	[illegible]
Dublin	[illegible]	Louisiana	[illegible]	Utica	[illegible]
Dumfries	[illegible]	Madeira	[illegible]	Venice	[illegible]
East Hampton	[illegible]		[illegible]	Vera Cruz	[illegible]
Edinburgh	[illegible]	Manchester	36.14	Vienna	[illegible]
	[illegible]		43	Washington	[illegible]
Fairfield	[illegible]	Marseilles	[illegible]	West Point	[illegible]

Average rainfall in England for a number of years was, South and East [illegible]; West and hilly [illegible] to [illegible] ins., and percolation of it was estimated at [illegible] per cent.

Mean volume of water in a cube foot of air in England is [illegible] *grains.*

Globe, mean depth .... [illegible] ins.
Cape of Good Hope, in [illegible] .... in 3 hours, [illegible] "
At Khassya, in 6 rainy months .... 550 ins.; in 1 day, [illegible] "

Evaporation.—Mean daily evaporation in India .22 inch; greatest [illegible]; in [illegible] [illegible] when mean depth of rainfall was [illegible] ins. in [illegible] years, evap[illegible] was for a like period [illegible] ins., and in Lancashire, Eng., when fall was [illegible] evaporation was 25.65.

Volume of Rainfall.

Rainfall, depth in ins. × 2 323 200 = cube feet per sq. mile.
" × 17 378 74 = millions of gallons per sq. mile.
" × 3630 = cube feet per acre.
" × 27 154.3 = gallons per acre.

Mineral Waters are divided into 5 groups, viz.:

1. Carbonated, containing pure Carbonic acid—as, Seltzer, Germany; Spa, Belgium; Pyrmont, Westphalia; Seidlitz, Bohemia; and Sweet Springs, Virginia.

2. Sulphurous, containing Sulphuretted hydrogen—as, Harrowgate and Cheltenham, England; Aix-la-Chapelle, Prussia; Blue Lick, Ky.; Sulphur Springs, Va., etc.

3. Alkaline, containing Carbonate of soda—these are rare, as, Vichy, Ems

te, containing Carbonate of iron—as, Hampstead, Tunbridge, Chelten-
ghton, England; Spa, Belgium; Ballston and Saratoga, N. Y.; and
.

ntaining salts—as, Epsom, Cheltenham, and Bath, England; Baden-
ltzer, Germany; Kissingen, Bavaria; Plombières, France; Seidlitz,
ıcca, Italy; Yellow Springs, Ohio; Warm Springs, N. C.; Congress
; and Grenville, Ky.

ief Rules for Qualitative Analysis of Mineral Waters.

to be determined, in examination of a mineral water, is to which of
does water in question belong.

eddens blue litmus paper before boiling, but not afterwards, and blue
ned paper is restored upon warming, it is Carbonated.

esses a nauseous odor, and gives a black precipitate, with acetate of
hurous.

ddition of a few drops of hydrochloric acid, it gives a blue precipitate,
r red prussiate of potash, water is a Chalybeate.

res blue color to litmus paper after boiling, it is Alkaline.

esses neither of above properties in a marked degree, and leaves a
upon evaporation, it is a Saline water.

: canal water contains .05 } of its volume of gaseous matter.
r well water " .07 }

Re-agents.

er is pure it will not become turbid, or produce a precipitate
following *Re-agents:*

ter, if a precipitate or opaqueness appear, Carbonic Acid is present.
Barium indicates Sulphates, *Nitrate of Silver*, Chlorides, and *Oxalate*
Lime salts. *Sulphide of Hydrogen*, slightly acid, Antimony, Arsenic,
Gold, Platinum, Mercury, Silver, Lead, Bismuth, and Cadmium; *Sul-*
monium, solution alkaloid by ammonia, Nickel, Cobalt, Manganese,
ımina, and Chromium. *Chloride of Mercury or Gold* and *Sulphate of*
matter.

Filter Beds.

feet 6 ins.; Coarse sand, 6 ins.; Clean shells, 6 ins., and Clean gravel
er 700 gallons water in 24 hours by gravitation.

ER. *Composition of it per volume:*

dium (common salt)..	2.51	Carbonate of Lime / " of Magnesia }	.02
Magnesium...........	.53		
"	.33	Sulphate of Lime................	.01
		Water..........................	96.6

is of Dr. Murray, at specific gravity of 1.029, it contains

f Soda.............	220.01	Muriate of Magnesia........	42.08
of Soda............	33.16	Muriate of Lime............	7.84
			303.09

contains .030309 parts of salt $= \frac{1}{88}$ part of its weight.

ıme of solid matter in solution is 3.4 per cent., .75 of which is
.

Points at Different Degrees of Saturation.

t,	Boiling Point.	Salt, by Weight, in 100 Parts.	Boiling Point.		Boiling int.
	213.2°	$15.15 = \frac{5}{88}$	217.9°		
	214.4°	$18.18 = \frac{6}{88}$	219°		
	215.5°	$21.22 = \frac{7}{88}$	220.2°		
	216.7°	$24.25 = \frac{8}{88}$	221.4°	*,	

* Saturated.

To Compute Number of Teeth.

RULE.—Divide circumference by pitch.

To Compute Number of Teeth in a Pinion or F to have a given Velocity.

RULE.—Multiply velocity of driver by its number of teeth, a product by velocity of driven.

EXAMPLE I.—Velocity of a driver is 16 revolutions, number of its tee velocity of pinion is 48; what is number of its teeth?

$$16 \times 54 \div 48 = 18 \textit{ teeth.}$$

2.—A wheel having 75 teeth is making 16 revolutions per minute; wh ber of teeth required in pinion to make 24 revolutions in same time?

$$16 \times 75 \div 24 = 50 \textit{ teeth.}$$

To Compute Proportional Radius of a Wheel or]

RULE.—Multiply length of line of centres by number of teeth for wheel, and in pinion, for pinion, and divide by number of teet wheel and pinion.

EXAMPLE.—Line of centres of a wheel and pinion is 36 ins., and numb in wheel is 60, and in pinion 18; what are their radii?

$$\frac{36 \times 60}{60 + 18} = 27.69 \textit{ ins. wheel.} \quad \frac{36 \times 18}{60 + 18} = 8.3 \textit{ ins. pinion.}$$

To Compute Diameter of a Pinion.

When Diameter of Wheel and Number of Teeth in Wheel and P given. RULE.—Multiply diameter of wheel by number of teeth i and divide product by number of teeth in wheel.

EXAMPLE.—Diameter of a wheel is 25 ins., number of its teeth 210, an of teeth in pinion 30; what is diameter of pinion?

$$25 \times 30 \div 210 = 3.57 \textit{ ins.}$$

To Compute Number of Teeth required in a T Wheels to produce a given Velocity.

RULE.—Multiply number of teeth in driver by its number of re and divide product by number of revolutions of each pinion, for ea and pinion.

EXAMPLE.—If a driver in a train of three wheels has 90 teeth, and mak lutions, and velocities required are 2, 10, and 18, what are number of teet of other two?

$10 : 90 :: 2 : 18 =$ *teeth in 2d wheel.* $\quad 18 : 90 :: 2 : 10 =$ *teeth in 3d*

To Compute Velocity of a Pinion.

RULE.—Divide diameter, circumference, or number of teeth in d e may be, by diameter, etc., of pinion.

there are a Series or Train of Wheels and Pinions. RULE.- product of diameter, circumference, or number of teeth i ed product of diameter, etc., of pinions.

If a wheel of 32 teeth drives a pinion of 10, upon axis of wh riving a pinion of 8, what are revolutions of last?

$$\frac{32}{10} \times \frac{30}{8} = \frac{960}{80} = 12 \textit{ revolutions.}$$

of wheels are 6, 9, 9, 10, and 12 ins.; of pinions, revolutions of driving shaft or prime mover is n?

$$\frac{\times 10}{6} = \frac{583200}{7776} = 75 \textit{ revolutions.}$$

Compute Proportion that Velocities of Wheels in a Train should bear to one another.

LE.—Subtract less velocity from greater, and divide remainder by one ıan number of wheels in train quotient is number, rising in arithmet- rogression from less to greater velocity.

MPLE.—What should be velocities of 3 wheels to produce 18 revolutions, the making 3?

$\frac{-3 = 15}{-1 = 2} = 7.5 =$ *number to be added to velocity of driver* $= 7.5 + 3 = 10.5$, and $\cdot 7.5 = 18$ *revolutions*. Hence 3, 10.5, and 18 *are velocities of three wheels.*

Pitch of Wheels.

Compute Diameter of a Wheel for a given Pitch, or Pitch for a given Diameter.

From 8 *to* 192 *Teeth.*

Diameter.	No. of Teeth.	Diameter.	No. of Teeth.	Diameter.	No. of Teeth.	Diameter.	No. of Teeth.	Diameter.
2.61	45	14.33	82	26.11	119	37.88	156	49.66
2.93	46	14.65	83	26.43	120	38.2	157	49.98
3.24	47	14.97	84	26.74	121	38.52	158	50.3
3.55	48	15.29	85	27.06	122	38.84	159	50.61
3.86	49	15.61	86	27.38	123	39.16	160	50.93
4.18	50	15.93	87	27.7	124	39.47	161	51.25
4.49	51	16.24	88	28.02	125	39.79	162	51.57
4.81	52	16.56	89	28.33	126	40.11	163	51.89
5.12	53	16.88	90	28.65	127	40.43	164	52.21
5.44	54	17.2	91	28.97	128	40.75	165	52.52
5.76	55	17.52	92	29.29	129	41.07	166	52.84
6.07	56	17.8	93	29.61	130	41.38	167	53.16
6.39	57	18.15	94	29.93	131	41.7	168	53.48
6.71	58	18.47	95	30.24	132	42.02	169	53.8
7.03	59	18.79	96	30.56	133	42.34	170	54.12
7.34	60	19.11	97	30.88	134	42.66	171	54.43
7.66	61	19.42	98	31.2	135	42.98	172	54.75
7.98	62	19.74	99	31.52	136	43.29	173	55.07
8.3	63	20.06	100	31.84	137	43.61	174	55.39
8.61	64	20.38	101	32.15	138	43.93	175	55.71
8.93	65	20.7	102	32.47	139	44.25	176	56.02
9.25	66	21.02	103	32.79	140	44.57	177	56.34
9.57	67	21.33	104	33.11	141	44.88	178	56.66
9.88	68	21.65	105	33.43	142	45.2	179	56.98
10.2	69	21.97	106	33.74	143	45.52	180	57.23
10.52	70	22.29	107	34.06	144	45.84	181	57.62
10.84	71	22.61	108	34.38	145	46.16	182	57.93
11.16	72	22.92	109	34.7	146	46.48	183	58.25
11.47	73	23.24	110	35.02	147	46.79	184	58.57
11.79	74	23.56	111	35.34	148	47.11	185	58.89
12.11	75	23.88	112	35.65	149	47.43	186	
12.43	76	24.2	113	35.97	150	47.75	187	
12.74	77	24.52	114	36.29	151	48.07	188	
13.06	78	24.83	115	36.61	152	48.39	189	
13.38	79	25.15	116	36.93	153	48.7	190	
13.7	80	25.47	117	37.25	154	49.02	191	
14.02	81	25.79	118	37.56	155	49.34	192	

ch in this table is *true* pitch, as before described.

To Compute Circumference of a Wheel.

ULE.—Multiply number of teeth by their pitch.

To Compute Revolutions of a Wheel or Pinion.

RULE.—Multiply diameter or circumference of wheel or number of its teeth in ins., as case may be, by number of its revolutions, and divide product by diameter, circumference, or number of teeth in pinion.

EXAMPLE.—A pinion 10 ins. in diameter is driven by a wheel 2 feet in diameter making 46 revolutions per minute; what is number of revolutions of pinion?

$$2 \times 12 \times 46 \div 10 = 110.4 \textit{ revolutions.}$$

To Compute Number of Teeth of a Wheel for a given Diameter and Pitch.

RULE.—Divide diameter by pitch, and opposite to quotient in preceding table is given number of teeth.

EXAMPLE.—Diam. of wheel is 40 ins., and pitch 1.675; what is number of its teeth?

$40 \div 1.675 = 23.88$, and opposite thereto in table is $75 =$ *number of teeth.*

To Compute Diameter of a Wheel for a given Pitch and Number of Teeth.

RULE.—Multiply diameter in preceding table for number of teeth by pitch, and product will give diameter at pitch circle.

EXAMPLE.—What is diameter of a wheel to contain 48 teeth of 2.5 ins. pitch?

$$15.29 \times 2.5 = 38.225 \textit{ ins.}$$

To Compute Pitch of a Wheel for a given Diameter and Number of Teeth.

RULE.—Divide diameter of wheel by diameter in table for number of teeth, and quotient will give pitch.

EXAMPLE.—What is pitch of a wheel when diameter of it is 50.94 ins., and number of its teeth 80?

$$50.94 \div 25.47 = 2 \textit{ ins.}$$

General Illustrations.

1.—A wheel 96 ins. in diameter, making 42 revolutions per minute, is to drive a shaft 75 revolutions per minute; what should be diameter of pinion?

$$96 \times 42 \div 75 = 53.76 \textit{ ins.}$$

2.—If a pinion is to make 20 revolutions per minute, required diameter of another to make 58 revolutions in same time.

$58 \div 20 = 2.9 =$ *ratio of their diameters.* Hence, if one to make 20 revolutions is given a diameter of 30 ins., other will be $30 \div 2.9 = 10.345$ *ins.*

3.—Required diameter of a pinion to make 12.5 revolutions in same time as one of 32 ins. diameter making 26.

$$32 \times 26 \div 12.5 = 66.56 \textit{ ins.}$$

4.—A shaft, having 22 revolutions per minute, is to drive another shaft at rate of 15, distance between two shafts upon line of centres is 45 ins.; what should be diameter of wheels?

Then, 1st. $22 + 15 : 22 :: 45 : 26.75 =$ *ins. in radius of pinion.*
2d. $22 + 15 : 15 :: 45 : 18.24 =$ *ins. in radius of spur.*

5.—A driving shaft, having 16 revolutions per minute, is to drive a shaft 81 revolutions per minute, motion to be communicated by two geared wheels and two pulleys, with an intermediate shaft; driving wheel is to contain 54 teeth, and driving pulley upon driven shaft is to be 25 ins. in diameter; required number of teeth in driven wheel, and diameter of driven pulley.

Let driven wheel have a velocity of $\sqrt{16 \times 81} = 36$, a mean proportional between extreme velocities 16 and 81.

Then, 1st. $36 : 16 :: 54 : 24 \quad =$ *teeth in driven wheel.*
2d. $81 : 36 :: 25 : 11.11 =$ *ins. diameter of driven pulley.*

6.—If, as in preceding case, whole number of revolutions of driving shaft, number of teeth in its wheel, and diameters of pulleys are given, what are revolutions of shafts?

Then, 1st. $18 : 16 :: 54 : 48 =$ revolutions of intermediate shaft.
2d. $15 : 48 :: 25 : 80 =$ revolutions of driven shaft.

Teeth of Wheels.

picycloidal.—In order that teeth of wheels and pinions should work .y and without unnecessary rubbing friction, the face (*from pitch line* ɔ) of the outline should be determined by an epicycloidal curve (see 228), and that of the flank (*from pitch line to base*) by an hypocycloidal ılso page 228).

hen generating circle is equal to half diameter of pitch circle, hypocy- ıl described by it is a straight diametrical line, and consequently out- ɔf a flank is a right line, and radial to centre of wheel.

a like generating circle is used to describe face of a tooth of other wheel ɑion respectively, the wheel and pinion will operate evenly.

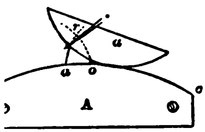
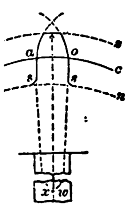


ILLUSTRATION.—Determine all elements of wheel —viz., Pitch circle, Number of teeth, Pitch, Length, Face, and Flank.

Cut a template A to pitch circle *c c* of wheel, and secure it temporarily to a board.

Having determined depth of tooth, set it off on pitch line, as *a o*, Fig. 1, and above it apply a second template, *a*; radius of wheel is equal to half s of pinion; insert into, or attach exactly at its edge, a tracer ., roll template ng A, and tracer will describe an epicycloidal curve, *a r*, and by inverting *a* ibe *o r*, and faces of a tooth are delineated.



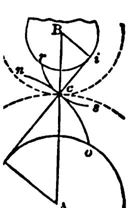
To describe flanks, define pitch line *c c*, Fig. 2, and arc *n n*, drawn at base of teeth or board A (as in Fig. 1), secure a strip of wood, *w*, equal in length to radius of wheel, and locate centre of it. *x*, draw radii *x a* and *x o*, and they will define flanks, which should be filleted, as shown at *s s*. Define arc *z z*, and length of tooth is determined.

Proceed in like manner conversely for teeth of pinion, and wheel and pinion thus constructed will operate truly.

In construction of the teeth of a wheel or pinion in the pattern-shop, it is customary to construct the wheel or pinion complete, out to face of wheel at base of teeth, and then to insert the teeth in rough, approximately ed blocks, by a dovetail at their base, fitting into face of wheel, and then ɔutline of a tooth is described thereon; the block is then removed, fin- l as a tooth, replaced, fastened, and filleted.

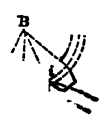
Involute.

ːeth of two wheels will work truly together when their face is that of an *'ute* (see page 229), and that two such wheels should work truly, the es from which the involute lines for each wheel are generated must be ɜntric with the wheels, with diameters in same ratio as those of the wheels.



Assume A *c*, B *c*, Fig. 3, pitch radii of two wheels designed to work together, through *c*, draw a right line, *e i*, and with perpendiculars *e c*, *i c*, describe arcs *n o*, *r s*, and involutes *n c o* and *r c s* define a face of each of the teeth.

To describe teeth of a pair of wheels of which A *c*, B *c*, Fig are pitch radii, draw *c i*, *c e*, ' pendicular to radials B *i* and and they are to be taken as radials of the involute arcs i which the faces of the teeth to be defined; then fillet flanks base, as before described, Fig. 2.


4.

volute teeth will work with truth, even at varyin ınces apart of the centres of the wheels, and any whe aion, however varied their diameters.

To Compute Depth of a Tooth.

When Stress is given. RULE.—Extract square root of stress, and mul- it by .02 for cast iron, and .027 for hard wood.

When IP *is given.* RULE.—Extract square root of quotient of IP di- l by velocity in feet per second, and multiply it by .466 for cast iron, .637 for hard wood.

AMPLE.—IP to be transmitted by a tooth of cast iron is 60, and velocity of it pitch-line is 6.66 feet per second; what should be depth of tooth?

$$\sqrt{\frac{60}{6.66}} \times .466 = 1.398 \textit{ ins.}$$

To Compute IP of a Tooth.

JLE.—Multiply pressure at pitch-line by its velocity in feet per minute, livide product by 33 000.

AMPLE.—What is IP of a tooth of dimensions and at velocity given in preced- xample.

$$4886 \times 6.66 \times 60'' \div 33\,000 = 59.16 \textit{ horses.}$$

'o Compute Stress that may be borne by a Tooth.

:LE.—Multiply *Coefficient* of material of tooth to resist a transverse n, as estimated for this character of stress, by breadth and square of its h, and divide product by extreme length of it in decimal of a foot.

AMPLE.—Dimensions of a cast-iron tooth in a wheel are 1.38 ins. in depth, 2.1 n length, and 7.5 ins. in breadth; what is the stress it will bear?

Coefficient assumed at 60. $\frac{60 \times 7.5 \times 1.38^2}{2.1 \div 12} = 4897$ *lbs.*

llowing deductions by the rules of different authors for like elements are sub- :d for a cast-iron tooth:

ı....... 3 *ins.* | Depth.... 1.38 *ins.* | Breadth... 7.5 *ins.* | Length.... 2.1 *ins.*

AL POWER IN STRESS EXERTED *·locity of 400 feet per min., 4886 lbs.*	Depth of Tooth.	ACTUAL POWER IN STRESS EXERTED *at a velocity of 400 feet per min., 4886 lbs.*	Depth of Tooth.
	Ins.		Ins.
bove Rule $\sqrt{\frac{H}{v}} \times .446$.....	1.398*	*By Rankine* $\sqrt{\frac{W}{1500}}$..........	1.8
'airbairn $.025\sqrt{W}$.........	1.75	" *Tredgold* $\frac{3}{4}\sqrt{\frac{H}{v}}$..........	2.25
mperial Journal $\sqrt{\frac{W}{1576}}$..	1.76	" *Buchanan* $\sqrt{\frac{.556\,H}{v}}$.......	2.24

representing horse-power (60), W *stress in lbs., and v velocity in feet per second.*

Depth, Pitch, and Breadth. (*M. Morin.*)

:ast iron............................... $.028\sqrt{W} = d$. $.057\sqrt{W} = P$.
lard wood............................... $.038\sqrt{W} = d$. $.079\sqrt{W} = P$.

representing weight or stress upon tooth in lbs., d depth of tooth, and P *pitch s.*

hen velocity of pitch-circle does not exceed 5 feet pe[illegible] $= 4\,d$, ı it exceeds 5 feet $b = 5\,d$, and if wheels are exposed [illegible]

:presenting breadth.

USTRATION.—Assume pressure at pitch-line of [illegible] iron w[illegible] 6000 lbs., and velocity 5 feet per second.

:n $.028\sqrt{6000} = 2.17$ *ins. Depth*, and $.057\sqrt{}$[illegible] *ins. Pi*[illegible]

E.—For further Illustrations of Formation of Te[illegible] Willis[illegible] , Trundles, etc., see Mosely's Engineering, Shelton's [illegible] achinery of Construction, etc.

ıis depth, with a breadth of 7.5 ins., is .1 of ultimate [illegible] of A[illegible] ron.

PROPORTIONS OF WHEELS.

With six flat Arms and Ribs upon one side of them, as ; *or a in centre, as* .

Rim.—Depth, measured from base of teeth, .45 to .5 of pitch of teeth ing a web upon its inner surface .4 of pitch in depth and .25 to .3 of width.

NOTE.—When face of wheel is mortised, depth of rim should be 1.5 times and breadth of it 1.5 times breadth of tooth or cog.

Hub.—When eye is proportionate to stress upon wheel, hub shou twice diameter of eye. In other cases depth around eye should be .75 of pitch.

Arm.—Depth .4 to .45 of pitch. Breadth at rim 1.5 times pitch, in ing .5 inch per foot of length toward hub.

Rib upon one edge of arm, or Web in its centre, should be from .25 pitch in width, and .4 to .45 of it in depth.

When section of an arm differs from those above given, as with one a plane section, as , or with a double rib, as , its dimen should be proportioned to form of section.

In a wheel of greater relative diameter, length of hub and breadth of or of the rib or web, according as plane of arm is in that of wheel, or trariwise, should be made to exceed breadth of face of wheel (at the in order to give it resistance to lateral strain.

Number of arms in wheels should be as follows:

1.5 to 3.25 feet in diameter..........	4	5 to 8.5 feet in diameter.......	
3.25 " 5 " "	5	8.5 " 16 " "	
16 to 24 feet in diameter............	10		

With light wheels, number of arms should be increased, in order bet sustain rigidity of rim.

Mortise Wheels.—Their rim or face should be .9 pitch of tooth, and depth of rim of a solid wheel.

WINDING ENGINES.

With Winding Engines, for drawing coals, etc., out of a Pit, wh is required to give a certain number of revolutions, it is necessa have given diameter of *Drum* and thickness of rope, which is flat r and contrariwise.

To Compute Diameter of a Drum.

Where Flat Ropes are used, and are wound one part over the other. I —Divide depth of pit in ins. by product of number of revolutions and 3. and from quotient subtract product of thickness of rope and number o olutions; remainder is diameter in ins.

EXAMPLE.—If an engine makes 20 revolutions, depth of pit being 600 fee rope 1 inch, what should be diameter of drum?

$$\frac{600 \times 12}{20 \times 3.1416} - \overline{1 \times 20} = \frac{7200}{62.832} - 20 = 94.59 \textit{ ins.}$$

To Compute Diameter of Roll.

...LE.—To area of drum add area or edge surface of rope; then asc ... table of areas, or by calculation, diameter that gives ...iameter of Roll.

EXAMPLE.—What is diameter of roll in preceding example?

Area of $94.59 = 7027.2 + (\text{area of } \overline{7200 \times 1}) = 7200 = 14\,227.2$, and $\sqrt{14\,227.2 +}$ $154 = 151.85$ *ins.*

Or, Radius of drum is increased number of revolutions multiplied by thickness rope; as $\frac{94.59}{2} + \overline{20 \times 1} = 67.295$ *ins.*

To Compute Number of Revolutions.

RULE.—To area of drum add area of edge surface of rope; from diameter the circle having that area subtract diameter of drum, and divide re- ainder by twice thickness of rope; quotient will give number of revolutions.

EXAMPLE.—Length of a rope is 2600 ins., its thickness 1 inch, and diameter of um 20 ins.; what is number of revolutions?

Area of 20 + area of rope $= 314.16 + 2600 = 2914.16$, diameter of which is 60.91, d $\frac{60.91 - 20}{1 \times 2} = 20.45$ *revolutions.*

Or, subtract diameter of drum from diameter of roll, and divide remainder by ice thickness of rope; as $60.91 - 20 = 40.91$, and $40.91 \div \overline{1 \times 2} = 20.45$ *revolutions.*

o Compute Point of Meeting of Ascending and Descending Buckets when two or more are used.

To Compute Point of Meeting of Buckets. RULE.—Divide sum of length turns of rope by 2, and to quotient add length of last turn; divide sum · 2, multiply quotient by half number of revolutions, and product will ve distance from centre of drum at which buckets will meet.

NOTE 1.—Meetings will always be below half depth of pit.

2.—At half number of revolutions buckets will meet.

EXAMPLE.—Diameter of a drum is 9 feet, thickness of rope 1 inch, and revolu- ns 20; what is depth of pit, and at what distance from top will buckets meet?

$$\frac{28.54 + 38.48}{2} + \overline{38.48 \div 2} \times \frac{20}{2} = \frac{71.99 \times 10}{2} = 35.995 \times 10 = 359.95 \textit{ feet.}$$

To Compute this Depth. RULE.—To diameter of drum add thickness of pe in feet, and ascertain its circumference; to diameter of drum add quo- nt of product of twice thickness of rope and number of revolutions less 1, vided by 12 for a diameter, and circumference of this diameter is length last turn, also in feet; add these two lengths together, multiply their sum half number of revolutions, and product will give depth of pit.

) + thickness of rope $= 9 + \frac{1}{12}$ of $1 = 9.083$, which $\times\ 3.1416 = 28.54$ *feet = length first turn.* $9.0833 + \frac{1 \times 2 \times \overline{20 - 1}}{12} \times 3.1416 = 38.48$ *feet = length of last turn.*

$$\text{Then } 28.54 + 38.48 \times \frac{20}{2} = 67.02 \times 10 = 670.2 \textit{ feet, depth of pit.}$$

WINDMILLS.

Driving Shaft of a vertical windmill should be set at an elevating angle th horizon when set upon low ground, and at a depressing angle when set on elevated ground. Range of these angles is from 3° to 15°. A velocity wind of 10 feet per second is not generally sufficient to drive a loaded ll, and if velocity exceeds 35 feet per second the force is generally too eat for ordinary structures.

Angle of Sails should be from 18° to 30° at their least radius, and from to 17° at their greatest radius, mean angle being from 15° to 17° to plane motion of sails. Length of a whip (arm) is divided into 7 parts. ding over 6 parts.

Whip in parts of its length: Breadth .033, at top .016; Depth .025, .0125; Width of sail .33, at axis .2. Distance of sail from axis .c length of whip, and cross-bars 16 to 18 ins. from centres.

To Compute Angles of Sails.

$23° - \frac{18\,d^2}{r^2}$ = *angle of sail with plane of its motion at any part of it.* d *senting distance of part of sail from its axis, and r extreme radius of sail, both*

ILLUSTRATION.—Assume $r = 14$, and length of sail 12 feet, $d = .5$ of 12 or sixths of sail $= .5 \times 12 + (14 - 12) = 2 = 8$ feet.

$$\text{Then } 23° - \frac{18 \times 8^2}{14^2} = 23 - 5.88° = 17.12°.$$

Hence, angle of sail with axis $= 90° - 17.12° = 72.88°$.

If radius of sails is divided into 6 equal parts, angles at each of these part be as follows:

	Distance from Axis. 1	2	3	4	5
Angle of sail with axis	67.5°	69°	71.5°	75°	79.5°
" " with plane of motion	22.5°	21°	18.5°	15°	10.5°

To Compute Elements of Windmills.

$\frac{3.16\,v}{r'\,\sin.\,x} = n$; $\frac{11.5\,v}{r'} = n$; $.1047\,n = a\,v$; $\frac{A\,v^3}{1\,080\,000} =$

$\frac{\text{IP} \times 1\,080\,000}{v^3} = A$; $\sqrt{\frac{R^2 + r^2}{2}} = r'$. *v representing velocity of wind pe ond, r′ radius of centre of percussion of sails, and R and r outer and inner rad sails, all in feet, x mean angle of sail to plane of motion, n number of revolution arms per minute, a v angular velocity, A area of sails in sq. feet, and* IP *horse-p*

ILLUSTRATION.—If a windmill has 4 arms of 28 feet, with a mean angle (x) of with an area of sail of 150 sq. feet each, having an inner radius of 4 feet, and i erated by wind at a velocity of 40 feet per second; what are its elements?

Then $\frac{11.5 \times 40}{20} = n = 23$; $\sqrt{\frac{28^2 + 4^2}{2}} = r' = 20$ *feet*; $\frac{3.16 \times 40}{20 \times .275\,64} = n = 2$

$\frac{4 \times 150 \times 64\,000}{1\,080\,000} = \text{IP} = 35.55$; $\frac{35.55 \times 1\,080\,000}{64\,000} = A = 599.9$ *sq. feet.*

Deductions from Velocities varying from 4 to 9 Feet Second. (*Mr. Smeaton.*)

1. Velocity of windmill sails, so as to produce a maximum effect, is n ly as velocity of wind, their shape and position being same.

2. Load at maximum is nearly, but somewhat less than, as square of locity of wind, shape and position of sails being same.

3. Effects of same sails, at a maximum, are nearly, but somewhat than, as cubes of velocity of wind.

4. Load of same sails, at maximum, is nearly as squares, and their ef as cubes of their number of turns in a given time.

5. In sails where figure and position are similar, and velocity of wind same, number of revolutions in a given time will be reciprocally as radiu of sail.

. at a maximum, which sails of a similar figure and position t a given distance from centre of motion, will be as cube of rad

of sails of similar figure and position are as square of radius

remities of Dutch sails, as well as of enlarged sails when unloaded, or even loaded to a maximum that of wind.

ults of Experiments on Effect of Windmill Sails. ıen a vertical windmill is employed to grind corn, the millstone usuaakes 5 revolutions to 1 of the sail.

Vhen velocity of wind is 19 feet per second, sails make from 11 to 12 ıtions in a minute, and a mill will grind from 880 to 990 lbs. in an or about 22 440 lbs. in 24 hours.

Vhen velocity of wind is 30 feet per second, a mill will carry all sail, ıake 22 revolutions in a minute, grinding 1984 lbs. of flour in an hour, 616 lbs. in 24 hours.

esults of Operation of Windmills. (*A. R. Woolf, M. E.*)

Velocity of Wind 15 to 20 Miles per Hour.

Revolutions of Wheel and Gallons of Water raised per Minute.

Revolutions of Wheel.	Water raised to an Elevation of 25 Feet.	50 Feet.	100 Feet.	200 Feet.	Power developed.	Cost per Hour. Actual.*	Per HP.
No.	Gallons.	Gallons.	Gallons.	Gallons.	HP	Cents.	Cents.
70 to 75	6.16	3.02	—	—	.04	.60	15
60 to 65	19.18	9.56	4.75	—	.12	.70	5.8
50 to 55	45.14	22.57	11.25	5	.28	1.63	5.8
40 to 45	97.68	52.16	24.42	12.21	.61	2.83	4.6
35 to 40	124.95	63.75	31.25	15.94	.78	3.56	4.5
30 to 35	212.38	106.96	49.73	26.74	1.34	4.26	3.2

* Including interest at 5 per cent. per annum.

WOOD AND TIMBER.

lection of Standing Trees.—Wood grown in a moist soil is lighter, lecays sooner, than that grown in dry, sandy soil.

st *Timber* is that grown in a dark soil, intermixed with gravel. ır, Cypress, Willow, and all others which grow best in a wet soil, xceptions.

ırdest and densest woods, and least subject to decay, grow in warm ıtes; but they are more liable to split and warp in seasoning.

ees grown upon plains or in centre of forests are less dense than from edge of a forest, from side of a hill, or from open ground.

ees (in U. S.) should be selected in latter part of July or first part ugust; for at this season leaves of sound, healthy trees are fresh green, while those of unsound are beginning to turn yellow. A d, healthy tree is recognized by its top branches being well leaved, even and of a uniform color. A rounded top, few leaves, some of ı turned yellow, a rougher bark than common, covered with parasitic ;s, and with streaks or spots upon it, indicate a tree upon the de-. Decay of branches, and separation of bark from the wood, are lible indications that the wood is impaired.

'een timber contains 37 to 48 per cent. of liquids. ~e to ı seasoning one year, it loses from 17 to 25 pe n ıned it retains from 10 to 15 per cent.

cording to M. Leplay, green wood contains about ıt of moisture. In Central Europe, wood cut in wi ving summer, fully 40 per cent. of water, and whe ears retains from 15 to 20 per cent. of water.

lling Timber.—Most suitable time for felling timber is dsummer. Recent experiments indicate latter season a

A tree should be allowed to attain full maturity before being felled. Oak matures at 75 to 100 years and upwards, according to circumstances; Ash, Larch, and Elm at 75; and Spruce and Fir at 80. Age and rate of growth of a tree are indicated by number and width of the rings of annual increase which are exhibited in a cross-section of its body.

A tree should be cut as near to the ground as practicable, as the lower part furnishes best timber.

Dressing Timber.—As soon as a tree is felled, it should be stripped of its bark, raised from the ground, reduced to its required dimensions, and its sap-wood removed.

Inspection of Timber.—Quality of wood is in some degree indicated by its color, which should be nearly uniform, and a little deeper towards its centre, and free from sudden transitions of color. White spots indicate decay. Sap-wood is known by its white color; it is next to the bark, and soon rots.

Defects of Timber.

Wind-shakes are serious defects, being circular cracks separating the concentric layers of wood from each other.

Splits, Checks, and Cracks, extending toward centre, if deep and strongly marked, render timber unfit for use, unless purpose for which it is intended will admit of its being split through them.

Brash is when wood is porous, of a reddish color, and breaks short, without splinters. It is generally consequent upon decline of tree from age.

Belted is that which has been killed before being felled, or which has died from other causes. It is objectionable.

Knotty is that containing many knots, though sound; usually of stinted growth.

Twisted is when grain of it winds spirally; it is unfit for long pieces.

Dry-rot is indicated by yellow stains. Elm and Beech are soon affected, if left with the bark on.

Large or decayed knots injuriously affect strength of timber.

Heart-shake.—Split or cleft in centre of tree, dividing it into segments.

Star-shake.—Several splits radiating from centre of timber.

Cup-shake.—Curved splits separating the rings wholly or in part.

Rind-gall.—Curved swelling, usually caused by growth of layers over spot where a branch has been removed.

Upset.—Fibres injured by crushing.

Foxiness.—Yellow or red tinge, indicating incipient decay.

Doatiness.—A speckled stain.

Seasoning and Preserving Timber.

Seasoning is extraction or dissipation of the vegetable juices and moisture or solidification of the albumen. When wood is exposed to currents of air ...h temperature, the moisture evaporates too rapidly, and it cracks; ... temperature is high and sap remains, it ferments, and dry-rot

...quires time in which to season, very much in proportion to density ...

...is total immersion of timber in water, for purpose of ...when thus seasoned it is less liable to warp and crack, ...tle.

r purpose of seasoning, it should be piled under shelter and kept dry; ld have a free circulation of air, without being exposed to strong cur-. Bottom pieces should be placed upon skids, which should be free decay, raised not less than 2 feet from ground; a space of an inch ld intervene between pieces of same horizontal layers, and slats or piling-s placed between each layer, one near each end of pile, and others at ; distances, in order to keep the timber from winding. These strips ld be one over the other, and in large piles should not be less than 1 inch :. Light timber may be piled in upper portion of shelter, heavy timber ground floor. Each pile should contain but one description of timber, ;hey should be at least 2.5 feet apart.

should be repiled at intervals, and all pieces indicating decay should be ved, to prevent their affecting those which are still sound.

requires from 2 to 8 years to be seasoned thoroughly, according to its nsions, and it should be worked as soon as it is thoroughly dry, for it iorates after that time.

adual seasoning is most favorable to strength and durability of timber. ›us methods have been proposed for hastening the process, as *Steaming*, h has been applied with success; and results of experiments of various ›sses of saturating it with a solution of *Corrosive sublimate* and *Anti-* ; fluids are very satisfactory. Such process hardens and seasons wood, e same time that it secures it from dry-rot and from attacks of worms.

oods are densest and strongest at the roots and at their centres. Their gth decreasing with the decrease of their density.

k timber loses *one fifth of its weight* in seasoning, and about *one third* coming perfectly dry.

:ch pine, from the presence of pitch, requires time in excess of that due ə density of its fibre.

ıhogany should be seasoned slowly, Pine quickly. Whitewood should ·e dried artificially, as the effect of heat is to twist it.

lt water renders wood harder, heavier, and more durable than fresh.

ndition of timber, as to its soundness or decay, is readily recognized . struck with a quick blow.

mber that has been for a long time immersed in water, when brought the air and dried, becomes brashy and useless.

hen trees are barked in the spring, they should not be felled until the ;e is dead.

mber cannot be seasoned by either smoking or charring; but when it posed to worms or to the production of *fungi*, it is proper to smoke or it, and it may be partially seasoned by being boiled or steamed.

mber houses are best provided with blinds which k ... nd , but which can be turned to admit air in fine weath ... .d be kept entirely free from any pieces of decayed w

ln-drying is suited only for boards and pieces of small t to cause cracks and to impair the strength, unless y.

arring, *Painting*, or *covering* the surface *is highly inj* *ned wood*, as it effectually prevents drying of the in , in consequence of which fermentation and decay soon

mber is subject to *Common* or *Dry-rot*, former occasione sure to moisture and dryness, and as progress of it is from ring of the surface, if seasoned, with paint, tar, etc., is a pr

Common-rot is the consequence of its being piled in badly-ventilated sheds. Outward indications are yellow spots upon ends of pieces, and a yellowish dust in the checks and cracks, particularly where the pieces rest upon piling-strips.

Dry or Sap-rot is inherent in timber, and it is the putrefaction of the vegetable albumen. Sap wood contains a large proportion of fermentable elements.

Insects attack wood for the sugar or gum contained in it, and *fungi* subsist upon the albumen of wood; hence, to arrest dry-rot, the albumen must be either extracted or solidified.

Most effective method of preserving timber is that of expelling or exhausting its fluids, solidifying its albumen, and introducing an antiseptic liquid.

Strength of impregnated timber is not reduced, and its *resilience* is improved.

In desiccating timber by expelling its fluids by heat and air, its strength is increased fully 15 per cent.

The saturation of wood with creosote, tar, antiseptics, etc., preserves it from the attack of worms. Jarrow wood, from Australia, is not subject to their attack.

In a perfectly dry atmosphere durability of woods is almost unlimited. Rafters of roofs are known to have existed 1000 years, and piles submerged in fresh water have been found perfectly sound 800 years from period of their being driven.

Resistance of woods to extension is greater than that of compression.

Impregnation of Wood.

Several of the successful processes are as follows:

Kyan, 1832.—Saturated with corrosive sublimate. Solution 1 lb. of chloride of mercury to 4 gallons of water.

Burnett (Sir Wm.), 1838.—Impregnation with chloride of zinc by submitting the wood endwise to a pressure of 150 lbs. per sq. inch. Solution 1 lb. of the chloride to 4 gallons of water.

Boucheri.—Impregnation by submitting the wood endwise to a pressure of about 15 lbs. per sq. inch. Solution, 1 lb. of sulphate of copper to 12 gallons of water.

Bethel.—Impregnation by submitting the wood endwise to a pressure of 150 to 200 lbs. per sq. inch, with oil of creosote mixed with bituminous matter.

Robbins, 1865.—Aqueous vapor dissipated by the wood being heated in a chamber, the albumen solidified, then submitted to vapor of coal tar, resin, or bituminous oils, which, being at a temperature not less than 325°, readily takes the place of the vapor expelled by a temperature of 212°.

Hayford, 187-.—Aqueous vapor dissipated by the wood being heated in a chamber to a temperature of from 250° to 270°, the albumen solidified, then air introduced to assist the splitting of the outer surfaces. When vapor is dissipated, dead oils are introduced under a pressure of 75 lbs. per sq. inch.

Planks, Deals, and Battens.—When cut from Northern pine (*Pinus Sylvestris*) are termed *yellow* or *red* deal, and when cut from spruce (*Abies*, etc.) they are termed *white* deal.

Desiccated wood, when exposed to air under ordinary circumstances, absorbs 5 per cent. of water in the first three days; and will continue to absorb it until it reaches from 14 to 16 per cent., the amount varying with to condition of the atmosphere.

Durability of Various Woods.

Pieces 2 feet in Length, 1.5 ins. Square, driven 28.5 ins. into the Earth.

Wood.	Condition After 2.5 Years.	Condition After 5 Years.
Acacia	Good	Externally decayed, rest fectly sound.
Ash, Amer.	Much decayed	Decayed.
Cedar, Va.	Very good	Sound as when driven.
" Lebanon	Good	Tolerable.
Elm, Eng.	Much decayed	Entirely decayed.
" Can.	" "	Decayed.
Fir	" attacked	Much decayed.
Larch	Surface only attacked	Attacked in part only, re condition.
Oak, Can.	Very much decayed	Very rotten.
" Memel	" " "	" "
" Dantzic	" " "	" "
" Chestnut	Very good	Some moderately, most much, decayed.
Pine, pitch	Surface only attacked	Attacked in part only, re condition.
" yellow	Attacked	Much decayed.
" white	Very much decayed	Very rotten.
Teak	Very good	Somewhat soft, but good.

Effect of Creosoting.

Results of Experiments with Various Woods (E. R. Andrews).

Wood.		Water absorbed.	Wood.		Wa absor
		Per cent.			Per c
Spruce	dried	.2543	Hard pine	dried	.1
	creosoted	.0261		creosoted	.0
Oak	dried	.2	Gum, black	dried	1
	creosoted	.0		creosoted	.1
Cotton-wood	dried	.714	Birch, white	dried	.4
	creosoted	.347		creosoted	.1

Sesquoia Gigantea of California, dried, .4722; creosoted, .0.

Fluids will pass with the grain of wood with great facility, but wil enter it except to a very limited extent when applied externally.

Absorption of Preserving Solution by different W for a Period of 7 Days. *Average Lbs. per Cube Foot.*

Black Oak	3.6	Hemlock	2.6	Rock Oak	
Chestnut	3	Red Oak	3.9	White Oak	

Proportion of Water in various Woods.

Alder (*Betula alnus*)	41.6	Pine (*Pinus Sylvestris L.*)	
Ash (*Fraxinus excelsior*)	28.7	Red Beech (*Fagus sylvatica*)	
Beech (*Fagus sylvatica*)	33	Red Pine (*Pinus picea dur*)	
Birch (*Betula alba*)	30.8	Spruce (*Abies, alba, nigra, rubra, excelsa*)	
Elm (*Ulmus campestris*)	44.5	Sycamore (*Acer p*	
Horse-chestnut (*Æsculus hippocast.*)	38.2	White Oak (*Querc*	
Larch (*Pinus larix*)	48.6	White Pine (*Pinu*	
Mountain Ash (*Sorbus aucuparia*)	28.3	White Poplar (*Pop*	
Oak (*Quercus robur*)	34.7		

Willow (*Salis caprea*)

Decrease in Dimensions of Timber by

Woods.	Ins.		Ins.	Woods.
Cedar, Canada	14	to	13.25	Pitch Pine, South.
Elm	11	to	10.75	Spruce
Oak, English	12	to	11.625	White Pine, Americal
Pitch Pine, North	10×10	to	9.75×9.75	Yellow Pine, North.

Weight of a beam of English oak, when wet, was reduce from 972.25 to 630.5 lbs.

Weight of a Cube Foot of Oak and Yellow Pine.

Age.	White Oak, Va.		Yellow Pine, Va.		Live Oak.
	Round.	Square.	Round.	Square.	
Green....................	64.7	67.7	47.8	39.2	78.7
1 Year....................	53.6	53.5	39.8	34.2	—
2 Years....................	46	49.9	34.3	33.5	66.7

In England, Timber sawed into boards is classed as follows:

6.5 to 7 ins. in width, *Battens;* 8.5 to 10 ins., *Deals;* and 11 to 12 ins, *Planks.* (*See also page* 62.)

Distillation.—From a single cord of pitch pine distilled by chemical apparatus, following substances and in quantities stated have been obtained:

Charcoal................	50 bushels.	Pyroligneous Acid..........	100 gallons
Illuminating Gas....about	1000 cu. feet.	Spirits of Turpentine.......	20 "
Illuminating Oil and Tar...	50 gallons.	Tar........................	1 barrel
Pitch or Resin.............	1.5 barrels.	Wood Spirit................	5 gallons

Strength of Timber.

Results of experiments have satisfactorily proved: That deflection was sensibly proportional to load; That extension and compression were nearly the same, though former being the greater; That, to produce equal deflection, load, when placed in the centre, was to a load uniformly distributed, as .625 to 1; That deflection under equal loads is inversely as breadths and cubes of the depths, and directly as cubes of the spans. (*M. Morin.*)

It has also been shown, that density of wood varies very little with its age. That *coefficient* of elasticity diminishes after a certain age, and that it depends also on the dryness and the exposure of the ground where the wood is grown. Woods from a northerly exposure, on dry ground, have a high *coefficient*, while those from swamps or low moist ground have a low one. That tensile strength is influenced by age and exposure. The *coefficient* of elasticity of a tree cut down in full vigor, or before it arrives at this condition, does not present any sensible difference. That there is no limit of elasticity in wood, there being a permanent set for every extension.

Average Result of Experiments on Tensile Strength of Wood in Various Positions per Sq. Inch. (*MM. Chevandier and Wertheim.*)

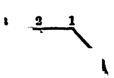
With the fibre, 6900 lbs. Radially, 683 lbs., and Tangentially, 723 lbs.

To Compute Volume of an Irregular Body.

By "Simpson's Rule."

OPERATION.—Take a right line in the figure for a base line, as A B, divide the figure into any number of equal parts, and compute the areas of their plane sections as 1, 2, 3, etc., at the points of division, by rules applicable to area of a plane. Then, erate these areas as if they were the ordinates of a plane curve or figure of same ·th as the figure, and result will give volume required.

STRATION.—Assume a figure having areas as follows, and A B = 24 feet.



Sections,	Areas,		Multiplier,	Products,
1	3	feet	1	3
2	5	"	4	20
3	7	"	2	14
4	9	"	4	36
5	11	"	1	11
				84

$\times 24 \div 4 \div 3 = 168$ cube feet.

MISCELLANEOUS MIXTURES.

Cements.

ends upon manner in which a cement is applied as upon the f, as best cement will prove worthless if improperly applied. ıles must be rigorously adhered to to attain success:

ment into intimate contact with surfaces to be united. This is best ıng pieces to be joined in cases where cement is melted by heat, as ıellac, marine glue, etc. Where solutions are used, cement must be nto surfaces, either with a brush (as in case of porcelain or glass), ; the two surfaces together (as in making a glue joint between pieces

cement as practicable should be allowed to remain between the united secure this, cement should be as liquid as practicable (thoroughly d with heat), and surfaces should be pressed closely into contact until ardened.

ould be allowed for cement to dry or harden, and this is particularly *il* cements, such as copal varnish, boiled oil, white lead, etc. When each .5 inch across, are joined by means of a layer of white lead en them, 6 months may elapse before cement in middle of joint be- At the end of a month the joint will be weak and easily separated; at years it may be so firm that the material will part anywhere else than nce, when article is to be used immediately, the only safe cements ich are liquefied by heat and which become hard when cold. A joint arine glue is firm an hour after it has been made. Next to cements ɩfied by heat are those which consist of substances dissolved in water A glue joint sets firmly in 24 hours; a joint made with shellac varnish in 2 or 3 days. Oil cements, which do not dry by evaporation, but idation (boiled oil, white lead, red lead, etc.) are slowest of all.

sin, Yellow Wax, and Venetian Red, each 1 oz.; melt and mix.

Aquarium.

ne white dry Sand, and Plaster of Paris, each 1 gill; finely pulverized l.

ly and make into a paste with boiled linseed oil to which drier has been added. Beat nd 4 or 5 hours before using it. After it has stood for 15 hours, however, it loses its ; cemented into a frame with this cement will resist percolation for either salt or fresh

Adhesive for Fractures of all Kinds.

l ground with Linseed-oil Varnish, and kept from contact with the air. v weeks to harden.

Stone or Iron.

equal parts of Sulphur and Pitch.

Brass to Glass.

—Resin, 5 ozs.; Beeswax, 1 oz.; Red Ochre or Venetian Red, in pow- ›ry earth thoroughly on a stove at above 212°. Melt Wax and Resin stir in powder by degrees. Stir until cold, lest earthy matter settle

ning brass-work to glass tubes, flasks, etc.

Chinese Waterproof.

—To 3 parts of Fresh Beaten Blood add 4 parts of a thin, pasty mass is produced, which can be used

ıich are to be made specially waterproof are painted twice, ‹ buildings of China are painted with *schio-liao*, which gives t ᵓ, but adds to their durability. Pasteboard treated with it r ıd.

China.

lk, dried and powdered, 10 ozs.; Quicklime, 1 oz.; Ca p air-tight. When used, a portion is to be mixed with a little w

Cisterns and Water-casks.

ıe, 8 parts; Linseed oil, boiled into a varnish with Lith hardens in about 48 hours, and renders the joints of wooden cisterns

Cloth or Leather.

Shellac, 1 part; Pitch, 2 parts; India Rubber, 4 parts; and Gutta Percha, 2 parts; cut small; Linseed oil, 2 parts; melted together and mixed.

Earthen and Glass Ware.

Heat article to be mended a little above 212°, then apply a thin coating of gum Shellac upon both surfaces of broken vessel.

Or, dissolve gum Shellac in alcohol, apply solution, and bind the parts firmly together until cement is dry.

Or, dilute white of egg with its bulk of water and beat up thoroughly. Mix to consistence of thin paste with powdered Quicklime.

Use immediately.

Entomologists'.

Thick Mastic Varnish and Isinglass size, equal parts.

Gutta Percha.

Melt together, in an iron pan, 2 parts Common Pitch and 1 part Gutta Percha.

Stir well together until thoroughly incorporated, and then pour liquid into cold water. When cold it is black, solid, and elastic; but it softens with heat, and at 100° is a thin fluid. It may be used as a soft paste, or in liquid state, and answers an excellent purpose in cementing metal, glass, porcelain, ivory, etc. It may be used instead of putty for glazing.

Glass.

Sorel's.—Mix commercial Zinc White with half its bulk of fine Sand, add a solution of Chloride of Zinc of 1.26 spec. grav., and mix thoroughly in a mortar.

Apply immediately, as it hardens very quickly.

Holes in Castings.

Sulphur in powder, 1 part; Sal-ammoniac, 2 parts; powdered Iron turnings, 80 parts. Make into a thick paste.

Make only as required for immediate use.

Hydraulic Paint.

Hydraulic cement mixed with oil forms an incombustible and waterproof paint for roofs of buildings, outhouses, walls, etc.

Iron Ware.

Sulphur, 2 parts; fine Black-lead, 1 part. Heat sulphur in an iron pan until it melts, then add the lead; stir well, and remove. When cool, break into pieces as required. Place upon opening of the ware to be mended, and solder with a hot iron.

Kerosene Lamps, etc.

Resin, 3 parts; Caustic Soda, 1; Water, 5, mixed with half its weight of Plaster of Paris.

It sets firmly in about three quarters of an hour. Is of great adhesive power, not permeable to kerosene, a low conductor of heat, and but superficially attacked by hot water.

Leather to Iron, Steel, or Glass.

1.—Glue, 1 quart, dissolved in Cider Vinegar; Venice Turpentine, 1 oz.; boil very gently or simmer for 12 hours.

Or, Glue and Isinglass equal parts, soak in water 10 hours, boil and add tannin until mixture becomes "ropy;" apply warm.

Remove surface of leather where it is to be applied.

2.—Steep leather in an infusion of Nutgall, spread a layer of hot Glue on surface of metal, and apply flesh side of leather under pressure.

Leather Belting.

Common Glue and Isinglass, equal parts, soaked for 10 hours in enough water to cover them. Bring gradually to a boiling heat and add pure Tannin until whole becomes ropy or appears alike to white of eggs.

Clean and rub surfaces to be joined, apply warm, and clamp firmly.

Molding and Temporary Adhesion.

Soft.—Melt Yellow Beeswax with its weight of Turpentine, and color with finely powdered Venetian red.

When cold it has the hardness of soap, but is easily softened and molded with the fingers.

Maltha, or Greek Mastic.

ne and Sand mixed in manner of mortar, and made into a proper consistency milk or size without water.

Marble.

.ster of Paris, in a saturated solution of Alum, baked in an oven, and reduced wder. Mixed with water, and color if required.

Metal to Glass.

pal Varnish, 15 parts; Drying Oil, 5; Turpentine, 3. Melt in a water bath and :o of Slaked Lime.

Mending Shells, etc.

m Arabic, 5 parts; Rock Candy, 2; and White Lead, enough to color.

Large Objects.

ollaston's White.—Beeswax, 1 oz.; Resin, 4 ozs.; powdered Plaster of Paris, 5 Melt together.

rm the edges of the object and apply warm.

means of this cement a piece of wood may be fastened to a chuck, which will hold when cool; and work is finished it may be removed by a smart stroke with tool. Any traces of cement may be red by Benzine.

Marble Workers and Coppersmiths.

hite of egg, mixed with finely-sifted Quicklime, will unite objects which are submitted to moisture.

Porcelain.

ld Plaster of Paris to a strong solution of Alum till mixture is of consistency ·eam.

ets readily, and is suited for cases in which large rather than small surfaces are to be united.

Rust Joint.

uick Setting.)—Sal-ammoniac in powder, 1 lb.; Flour of Sulphur, 2 lbs.; Iron ngs, 80 lbs. Made to a paste with water.

low Setting.)—Sal-ammoniac, 2 lbs.; Sulphur, 1 lb.; Iron borings, 200 lbs.

latter cement is best if joint is not required for immediate use.

Steam Boilers, Steam-pipes, etc.

nely powdered Litharge, 2 parts; very fine Sand, 1; and Quicklime slaked by sure to air, 1.

mixture may be kept for any length of time without injuring. In using it, a portion is mixed aste with linseed oil, boiled or crude. Apply quickly, as it soon becomes hard.

ft.—Red or White Lead in oil, 4 parts; Iron borings, 2 to 3 parts.

ard.—Iron borings and salt water, and a small quantity of Sal-ammoniac with water.

Transparent—Glass.

dia-rubber, 1 part in 64 of chloroform; gum Mastic in powder, 16 to 24 parts. st for two days, with frequent shaking.

, pulverized Glass, 10 parts; powdered Fluor-spar, 20; soluble Silicate of Soda, Both glass and fluor-spar must be in finest practicable condition, which is best by shaking each in fine powder, with water, allowing coarser particles to de-, and then by pouring off remainder, which holds finest particles in suspension.

mixture must be made very rapidly, by quick stirring, and applied immediately.

Uniting Leather and Metal.

nsh metal with hot Gelatine; steep leather in an infusion of Nutgalls, hot, bring the two together.

Waterproof Mastic.

ed Lead, 1 part; ground Lime, 4 parts; sharp Sand and boiled Oil, 5 parts.

, Red Lead, 1 part; Whiting, 5; and sharp Sand and boiled Oil, 10.

Wood to Iron.

tharge and Glycerine.—Finely powdered Oxide of Lead (litharge) and Concen-ed Glycerine.

composition is insoluble in most acids, is unaffected by action of moderate heat, sets rapidly, equires an extraordinary hardness.

erner's.—Melt 1 lb. of Resin, and add .25 lb. of Pitch.

hile boiling add Brick dust to give required consistency. In winter it may *sary to add a little Tallow.*

GLUES.

Marine.

Dissolve India Rubber, 4 parts, in 34 parts of Coal-tar Naphtha; add powdered Shellac, 64 parts.

While mixture is hot pour it upon metal plates in sheets. When required for use, heat it, and apply with a brush.

Or, India Rubber, 1 part; Coal Tar, 12 parts; heat gently, mix, and add powdered Shellac, 20 parts. Cool. When used, heat to about 250°.

Or, Glue, 12 parts; Water, sufficient to dissolve; add Yellow Resin, 3 parts; and, when melted, add Turpentine, 4 parts.

Strong Glue.—Add Powdered Chalk to common Glue.

Mix thoroughly.

Mucilage.

Curd of Skim Milk (carefully freed from Cream or Oil), washed thoroughly, and dissolved to saturation in a cold concentrated solution of Borax.

This mucilage keeps well, and, as regards adhesive power, far surpasses gum Arabic.

Or, Oxide of Lead, 4 lbs.; Lamp-black, 2 lbs.; Sulphur, 5 ozs.; and India Rubber dissolved in Turpentine, 10 lbs.

Boil together until they are thoroughly combined.

Preservation of Mucilage.—A small quantity of Oil of Cloves poured into a bottle containing Gum Mucilage prevents it from becoming sour.

To Resist Moisture.

Glue, 5 parts; Resin, 4 parts; Red Ochre, 2 parts; mixed with least practicable quantity of water.

Or, Glue, 4 parts; Boiled Oil, 1 part, by weight; Oxide of Iron, 1 part.

Or, Glue, 1 lb., melted in 2 quarts of skimmed Milk.

Parchment.

Parchment Shavings, 1 lb.; Water, 6 quarts.

Boil until dissolved, then strain and evaporate slowly to proper consistence.

Rice, or Japanese.

Rice Flour; Water, sufficient quantity.

Mix together cold, then boil, stirring it during the time.

Liquid.

Glue, Water, and Vinegar, each 2 parts. Dissolve in a water-bath, then add Alcohol, 1 part.

Or, Cologne or strong Glue, 2.2 lbs.; Water, 1 quart; dissolve over a gentle heat; add Nitric Acid 36°, 7 ozs., in small quantities.

Remove from over fire, and cool.

Or, White Glue, 16 ozs.; White Lead, dry, 4 ozs.; Rain Water, 2 pints. Add Alcohol, 4 ozs., and continue heat for a few minutes.

Elastic and Sweet.—Stamps or Rolls.

Elastic.—Dissolve good Glue in water by a water-bath. Evaporate to a thick consistence, and add equal weight of Glycerine to Glue; submit to heat until all water is evaporated, and pour into molds or on plates.

Sweet.—Substitute Sugar for the Glycerine.

...re Engravings or Lithographs upon Wood.

... parts; Mastic in tears, 64 parts; Resin, 125 parts; Venice Tur... and Alcohol, 1000 parts by measure.

...WNING, OR BRONZING, LIQUID.

Sweet Spirit of Nitre, 1 oz.; Water, 1 pint.

...use.

Gun Barrels.

'Incture of Muriate of Iron, 1 oz.; Nitric Ether, 1 oz.; Sulphate ol uples; rain water, 1 pint. If the process is to be hurried, add 2 or y muriate of Mercury.

7 hen barrel is finished, let it remain a short time in lime-water, to neutralize any aci e penetrated; then rub it well with an iron wire scratch-brush.

After Browning. — Shellac, 1 oz.; Dragon's-blood, .25 oz.; rectified S ssolve and filter.

Dr, Nitric Acid, spec. grav. 1.2; Nitric Ether, Alcohol, and Muriate of I rt. Mix, then add Sulphate of Copper 2 parts, dissolved in Water 10 p

LACQUERS.

Small Arms, or Waterproof Paper.

Beeswax, 13 lbs.; Spirits Turpentine, 13 gallons; Boiled Linseed Oil, 1

All ingredients should be pure and of best quality. Heat them together in a copper o over a gentle fire, in a water-bath, until they are well mixed.

Bright Iron Work.

Linseed Oil, boiled, 80.5 parts; Litharge, 5.5 parts; White Lead, in oil, 1 esin, pulverized, 2.75 parts.

Add litharge to oil; simmer over a slow fire 3 hours; strain, and add resin and white ntly warmed, and stir until resin is dissolved.

Or, Amber, 6 parts; Turpentine, 6 parts; Resin, 1 part; Asphaltum, 1 rying Oil, 3 parts; heat and mix well.

Or, Shellac, 1 lb.; Asphaltum, 6 lbs.; and Turpentine, 1 gallon.

Iron and Steel.

Clear Mastic, 10 parts; Camphor, 5 parts; Sandarac, 15 parts; and E parts. Dissolve in Alcohol, filter, and apply cold.

Brass.

Shellac, 8 ozs.; Sandarac, 2 ozs.; Annatto, 2 ozs.; and Dragon's-blood ; and Alcohol, 1 gallon.

Or, Shellac, 8 ozs.; and Alcohol, 1 gallon. Heat article slightly, and ap th a soft brush.

Vood, Iron, or Walls, and rendering Cloth, Pap Waterproof.

Heat 120 lbs. Oil Varnish in one vessel, 33 lbs. Quicklime in 22 lbs. w ter. Soon as lime effervesces, add 55 lbs. melted India Rubber. Sti d pour into vessel of hot Varnish. Stir, strain, and cool.

When used, thin with Varnish and apply, preferably hot.

To Clean Soiled Engravings.

Ozone Bleach, 1 part; Water, 10; well mixed.

INKS.

Indelible, for Marking Linen, etc.

1.—Juice of Sloes, 1 pint; Gum, .5 oz.

This requires no "preparation" or mordant, and is very durable.

2.—Nitrate of Silver, 1 part; Water, 6 parts; Gum, 1 part; Dissolve.

3.—Lunar Caustic, 2 parts; Sap Green and Gum Arabic, each 1 part; di stilled water.

"*Preparation.*"—Soda, 1 oz.; Water, 1 pint; Sap Green, .5 dr d wet article to be marked, then dry and apply the ink.

Perpetual, for Tomb-stones, Marble, etc.—Pitch, 11 parts; La rpentine sufficient. Warm and mix.

Copying Ink.—Add 1 oz. Sugar to a pint of ordinary Ink.

SOLDERING.

Base for Soldering.

Strips of Zinc in diluted Muriatic, Nitric, or Sulphuric Acid, unti mposed as acid will effect. Add Mercury, let it stand for a day ater, and bottle the Mercury.

When required, rub surface to be soldered with a cloth dipped in th

VARNISHES.

Waterproof.

Flour of Sulphur, 1 lb.; Linseed Oil, 1 gall.; boil them until they are thoroughly combined.

Good for waterproof textile fabrics.

Harness.

India Rubber, .5 lb.; Spirits of Turpentine, 1 gall.; dissolve into a jelly; then mix hot Linseed Oil, equal parts with the mass, and incorporate them well over a slow fire.

Fastening Leather on Top Rollers.

Gum Arabic, 2.75 ozs., and a like volume of Isinglass, dissolved in Water.

To Preserve Glass from the Sun.

Reduce a quantity of Gum Tragacanth to fine powder, and dissolve it for 24 hours in white of egg well beat up.

Water-color Drawings.

Canada Balsam, 1 part; Oil of Turpentine, 2 parts.
Mix and size drawing before applying.

Objects of Natural History, Shells, Fish, etc.

Mucilage of Gum Tragacanth and of Gum Arabic, each 1 oz.
Mix, and add spirit with Corrosive Sublimate, to precipitate the more stringy portion of the Gum.

Iron and Steel.

Mercury, 120 parts; Tin, 10 parts; Green Vitriol, 20 parts; Hydrochloric Acid of 1.2 sp. gr., 15 parts, and pure Water, 120 parts.

Blackboards.

Shellac Varnish, 5 gallons; Lamp-black, 5 ozs.; fine Emery, 3 ozs.; thin with Alcohol, and lay in 3 coats.

Black.

Heat, to boiling, Linseed Oil Varnish, 10 parts, with Burnt Umber, 2 parts, and powdered Asphaltum, 1 part.
When cooled, dilute with Spirits of Turpentine as may be required.

Balloon.

Melt India Rubber in small pieces with its weight of boiled Linseed Oil.
Thin with Oil of Turpentine.

Transfer.

Alcohol, 5 ozs.; pure Venice Turpentine, 4 ozs.; Mastic, 1 oz.

To render Canvas Waterproof and Pliable.

Yellow Soap, 1 lb, boiled in 6 pints of Water, add, while hot, to 112 lbs. of oil Paint.

Waterproof Bags.

Pitch, 8 parts, Wax and Tallow, each 1 part.

To Clean Varnish.

Mix a lye of Potash or Soda, with a little powdered Chalk.

STAINING.

Wood and Ivory.

Yellow ... Acid will produce it on wood.

...azil Wood in Stale Urine, in the proportion of 1 lb. to ... on when boiling hot, also Alum water before it dries ... lood in Spirits of Wine.

... Nitric Acid

...erdigris in Nitric Acid, which will turn ... th boiling hot.

... amoniac into four times its weight of

... dissolved in water and put on hot.

MISCELLANEOUS.

Blacking for Harness.

, .5 lb.; Ivory Black, 2 ozs.; Spirits of Turpentine, 1 oz.; Prussian Blue
oil, 1 oz.; Copal Varnish, .25 oz.
t and stir it into other ingredients before mixture is quite cold; make it
Rub a little upon a brush, and apply it upon harness, then polish lightly

To Clean Brass Ornaments.

naments that have not been gilt or lackered may be cleaned, and a very
lor given to them, by washing them in Alum boiled in strong Lye, in the
of an ounce to a pint, and afterwards rubbing them with strong Tripoli.

To Harden Drills, Chisels, etc.

them in Mercury.

To Clean Coral.

ith equal parts Spirits of Salts and cold water.
n a hot solution of Potash or Chloride of Lime. If much discolored, let
n solution for a few hours.

Blacking, without Polishing.

, 4 ozs.; Lamp-black, .5 oz.; Yeast, a table-spoonful; Eggs, 2; Olive Oil,
ful; Turpentine, a teaspoonful. Mix well.
ied with a sponge, without brushing.

Dubbing.

lbs.; Tallow, 1 lb.; Train-oil, 1 gallon.

Anti-friction Grease.

oo lbs.; Palm-oil, 70 lbs. Boiled together, and when cooled to 80°, strain
sieve, and mix with 28 lbs. of Soda, and 1.5 gallons of Water.
ter, take 25 lbs. more oil in place of the Tallow.
k Lead, 1 part; Lard, 4 parts.

To Attach Hair Felt to Boilers.

d, 1 lb.; White Lead, 3 lbs.; and Whiting, 8 lbs. Mixed with boiled Lin-
consistency of paint.

Pastils for Fumigating.

ıbic, 2 ozs.; Charcoal Powder, 5 ozs.; Cascarilla Bark, powdered, .75 oz.;
25 drachm. Mix together with water, and make into shape.

Writing upon Zinc Labels.—Horticultural.

100 grains of Chloride of Platinum in a pint of water; add a little Mu-
Lamp-black.
ımmoniac, 1 dr.; Verdigris, 1 dr.; Lamp-black, .5 dr.; Water, 10 drs. Mix.

To Remove old Ironmold.

en part stained with ink, remove this by use of Muriatic Acid diluted by
s its weight of water, when old and new stain will be removed.

To Cut India Rubber.

ıde of knife wet with water or a strong solution of Po

Adhesive for Rubber Belts.

ving surface with Boiled Oil or Cold Tallow, and the

Liard.

of finest Rape-oil, and 1 part of Caoutchouc, cut small.
r all dissolved.

To Preserve Leather Belting or Ho

arm Castor Oil. For hose, force it through it.

To Oil Leather Belting.

solution of India Rubber and Linseed Oil.

Dressing for Leather Belts.

1.—Beef Tallow, 1 part, and Castor Oil, 2 parts. Apply warm.

2.—Beef Tallow, 3 lbs.; Beeswax, 1 lb. Heated and applied warm to both sides.

Files.

Lay dull files in diluted Sulphuric Acid until they are bitten deep enough.

To Remove Oil from Leather.

Apply Aqua-ammonia.

To Clean Paint.

Wash with a solution of Pearlash in water. If greasy, use Quicklime.
Or, Extract of Litherium diluted with from 200 to 300 parts of water.

To Remove Paint.

Mix Soft Soap, 2 ozs., and Potash, 4 ozs., in boiling Water, with Quicklime, ½ lb.
Apply hot, and let remain for 1 day.
Or, Extract of Litherium, thinly brushed over the surface 2 or 3 times.

To Clean Marble.

Chalk, powdered, and Pumice-stone, each 1 part; Soda, 2 parts. Mix with water.
Wash the spots, then clean and wash off with Soap and Water.

Paste for Cleaning Metals.

Oxalic Acid, 1 part; Rottenstone, 6 parts. Mix with equal parts of Train Oil and Spirits of Turpentine.

Watchmaker's Oil, which never Corrodes or Thickens.

Place coils of thin Sheet Lead in a bottle with Olive Oil. Expose it to the sun for a few weeks, and pour off the clear oil.

Durable Paste.

Make common Flour paste rather thick (by mixing some Flour with a little cold water until it is of uniform consistency, and then stir it well while boiling water is being added to it); add a little Brown Sugar and Corrosive Sublimate, which will prevent fermentation, and a few drops of Oil of Lavender, which will prevent it becoming moldy. When dried, dissolve in water.

It will keep for two or three years in a covered vessel.

To Extract Grease from Stone or Marble.

Soft Soap, 1 part; Fuller's Earth, 2 parts; Potash, 1 part. Mix with boiling water.
Lay it upon the spots, and let it stand for a few hours.

Stains.

To Remove.—Stains of *Iodine* are removed by rectified Spirit; *Ink* stains by Oxalic or Superoxalate of Potash; *Ironmolds* by same; but if obstinate, moisten them with Ink, then remove them in the usual way.

Red spots upon black cloth, from acids, are removed by Spirits of Hartshorn, or other solutions of Ammonia.

Stains of Marking-ink, or Nitrate of Silver.—Wet stain with fresh solution of ...ide of Lime, and, after 10 or 15 minutes, if marks have become white, dip the ...olution of Ammonia or of Hyposulphite of Soda. In a few minutes wash ...water.

...he stained linen over a basin of hot water, and wet mark with Tinc...

...e Paste for Objects of Natural History.

...b.; Powdered Hellebore, 2 lbs.

...ottoms of Iron Steam-boilers.

...Red, 17 parts; Whiting, 6.5 parts; and Litharge...

...reserve Sails.

...he lime-water, and mix it with 120 gallons...

Whitewash.

ıtside exposure, slack Lime, .5 bushel, in a barrel; add common Salt, 1 lb.; › of Zinc, .5 lb.; and Sweet Milk, 1 gallon.

To Preserve Woodwork.

. Oil and finely powdered Charcoal, each 1 part; mix to the consistence of Apply 2 or 3 coats.

nposition is well adapted for casks, water-spouts, etc.

To Polish Wood.

ırface with Pumice Stone and water until the rising of the grain is removed. .th powdered Tripoli and boiled Linseed Oil, polish to a bright surface.

Paint for Window Glass.

ıe Green, .25 oz.; Sugar of Lead, 1 lb.; ground fine, in sufficient Linseed Oil en it. Mix to the consistency of cream, and apply with a soft brush.

ss should be well cleansed before the paint is applied. The above quantity is sufficient for feet of glass.

To Make Drain Tiles Porous.

ıwdust with the clay before burning.

SCELLANEOUS OPERATIONS AND ILLUSTRATIONS.

t is required to lay out a tract of land in form of a square, to be en- vith a post and rail fence, 5 rails high, and each rod of fence to con- rails. What must be side of this square to contain just as many ı there are rails in fence?

.TION. 1 mile = 320 *rods.* Then 320 × 320 ÷ 160, *sq. rods in an acre* = 640 .nd 320 × 4 *sides* and × 10 *rails* = 12 800 *rails per mile.*

as 640 *acres* : 12 800 *rails* :: 12 800 *acres* : 256 000 *rails, which will enclose* ıcres, and $\sqrt{256\,000} \times 69.5701$ = *number of yards in side of a sq. acre,* and *yards in a mile* = 20 *miles.*

Iow many fifteens can be counted with four fives?

OPERATION. $\dfrac{4 \times 3 \times 2 \times 1}{1 \times 2 \times 3} = \dfrac{24}{6} = 4.$

Vhat are the chances in favor of throwing one point with three dice?

.TION.—Assume a bet to be upon the ace. Then there will be 6 × 6 × 6 = 216 : *ways which the dice may present themselves, that is, with and without an ace.*

if the ace side of the die is excluded, *there will be* 5 *sides left,* and 5 × 5 × 5 *ays without the ace.*

fore, there will remain only 216 — 125 = 91 *ways in which there could be an* ıe chance, then, in favor of the ace is as 91 to 125; that is, out of 216 throws, ›ability is that it will come up 91 *times,* and lose 125 *times.*

:he hour and minute hand of a clock are exactly together at 12; re they next together?

ıTION.—As the minute hand runs 11 times faster thaı then, o :: 1 : 5 *min.* $27\frac{3}{11}$ *sec.* = *time past* 1 *o'clock.*

ıssume a cube inch of glass to weigh 1.49 ounce er .59, and of brandy .53. A gallon of this liqu. veighs 3.84 lbs., is thrown into sea-water. It is it will sink, and, if so, how much force will just bı

.TION. 3.84 × 12 ÷ 1.49 = 30.92 *cube ins. of glass in bot* be ins. in a gallon × .53 = 122.43 *ounces of brandy.*

bottle and brandy weigh 3.84 × 12 + 122.43 = 168.51 *o ube ins.,* which × .59 = 154.53 *ounces, weight of an equal*

68.51 — 154.53 = 13.98 *ounces, weight necessary to support*

6.—A fountain has 4 supply cocks, A, B, C, and D, and under it is a cistern, which can be filled by the cock A in 6 hours, by B in 8 hours, by C in 10 hours, and by D in 12 hours; now, the cistern has 4 holes, designated E, F, G, and H, and it can be emptied through E in 6 hours, F in 5 hours, G in 4 hours, and H in 3 hours. Suppose the cistern to be full of water, and that all the cocks and holes were opened together, in what time would the cistern be emptied?

Operation.—Assume the cistern to hold 120 gallons.

hrs.		gall.		hrs.		gall.		hrs.		gall.		hrs.		gall.	
If 6	:	120	::	1	:	20	*at* A.	If 6	:	120	::	1	:	20	*at* E.
8	:	120	::	1	:	15	*at* B.	5	:	120	::	1	:	24	*at* F.
10	:	120	::	1	:	12	*at* C.	4	:	120	::	1	:	30	*at* G.
12	:	120	::	1	:	10	*at* D.	3	:	120	::	1	:	40	*at* H.
Run in in 1 *hour*,						57	*gallons.*	*Run out in* 1 *hour*,						114	*gallons.*
														57	
								Run out in 1 *hour more than run in*,						57	*gallons.*

Then, as 57 *gallons* : 1 *hour* :: 120 *gallons* : 2.105+ *hours*.

7.—A cistern, containing 60 gallons of water, has 3 cocks for discharging it; one will empty it in 1 hour, a second in 2 hours, and a third in 3 hours; in what time will it be emptied if they are all opened together?

Operation.—1st, .5 would run out in 1 hour by the 2d cock, and .333 by the 3d; consequently, by the 3 would the reservoir be emptied in 1 hour. $.5+.333+1=\frac{3}{6}+\frac{2}{6}+\frac{6}{6}$, *being reduced to a common denominator, the sum of these* $3=\frac{11}{6}$; whence the proportion, $11:60::6:32\frac{8}{11}$ *minutes.*

8.—A reservoir has 2 cocks, through which it is supplied; by one of them it will fill in 40 minutes, and by the other in 50 minutes; it has also a discharging cock, by which, when full, it may be emptied in 25 minutes. If the 3 cocks are left open, in what time would the cistern be filled, assuming the velocity of the water to be uniform?

Operation.—The least common multiple of 40, 50, and 25, is 200.

Then, the 1st cock will fill it 5 times in 200 *minutes*, and the 2d, 4 times in 200 *minutes*, or both, 9 *times in* 200 *minutes;* and, as the discharge cock will empty it 8 *times in* 200 *minutes*, hence $9-8=1$, or once in 200 *minutes* $=3.2$ *hours.*

9.—The time of the day is between 4 and 5, and the hour and minute hands are exactly together; what is the time?

Operation.—Difference of speed of the hands is as 1 to $12=11$.

4 hours $\times 60=240$, which $\div 11=21$ *min.* 49.09 *sec., which is to be added to* 4 *hours.*

10.—Out of a pipe of wine containing 84 gallons, 10 were drawn off, and the vessel refilled with water, after which 10 gallons of the mixture were drawn off, and then 10 more of water were poured in, and so on for a third and fourth time. It is required to compute how much pure wine remained in the vessel, supposing the two fluids to have been thoroughly mixed.

Operation. $84-10=74$, *quantity after the* 1*st draught.*
Then, $84:10::74:8.8095$, and $74-8.8095=65.1905$, *quantity after* 2*d draught.*
$84:10::65.1905:7.7608$, and $65.1905-7.7608=57.4297$, *quantity after* 3*d draught.*
$84:10::57.4297:6.8367$, and $57.4297-6.8367=50.593$, *quantity after* 4*th draught,* $=$ *result required.*

11.—A reservoir having a capacity of 10000 cube feet, has an influx of 750 and a discharge of 1000 cube feet per day. In what time will it be emptied?

Operation. $\dfrac{10000}{1000-750}=40$ *days.*

The discharge being 1000 and the influx 1250 cube feet per hour

$\dfrac{10000}{1250-1000}=40$ hours $=1$ *day* 16 *hours.*

—A son asked his father how old he was. His father answered him : If you take away 5 from my years, and divide the remainder by 8, uotient will be one third of your age; but if you add 2 to your age, and iply the whole by 3, and then subtract 7 from the product, you will have umber of years of my age. What were the ages of father and son?

RATION.—Assume father's age 37.

n $37 - 5 = 32$, and $32 \div 8 = 4$, and $4 \times 3 = 12$, *son's age.* Again: $12 + 2 = 14$, $4 \times 3 = 42$, and $42 - 7 = 35$. Therefore $37 - 35 = 2$, *error too little.*

in: Assume father's age 45; then $45 - 5 = 40$, and $40 \div 8 = 5$. Therefore $= 15$, *son's age.* Again: $15 + 2 = 17$, and $17 \times 3 = 51$, and $51 - 7 = 44$. There- $5 - 44 = 1$, *error too little.*

nce (45 sup. $\times$ 2 error) — (37 sup. $\times$ 1 error) $= 90 - 37 = 53$, and $2 - 1 = 1$.

nsequently, 53 *is father's age.* Then $53 - 5 = 48$, and $48 \div 8 = 6 = .333$ *of son's* nd $6 \times 3 = 18$ *years, son's age.*

—Two companions have a parcel of guineas. Said A to B, if you will me one of your guineas I shall have as many as you have left. B re- , if you will give me one of your guineas I shall have twice as many as will have left. How many guineas had each of them?

ERATION.—Assume B had 6.

en A would have had 4, for $6 - 1 = 4 + 1 = 5$. Again: 4 (A's parcel) $- 1 = 3$, $+ 1 = 7$, and $3 \times 2 = 6$. Therefore $7 - 6 = 1$, *error too little.*

ain: Assume B had 8.

en A would have 6, for $8 - 1 = 6 + 1 = 7$. Again: 6 (A's parcel) $- 1 = 5$, and $= 9$, and $5 \times 2 = 10$. Therefore $10 - 9 = 1$, *error too great.*

nce $8 \times 1 = 8$, and $6 \times 1 = 6$. Then $8 + 6 = 14$, and $1 + 1 = 2$. Whence, di- g products by sum of errors, $14 \div 2 = 7 =$ B's *parcel,* and $7 - 1 = 5 + 1 = 6$ *when he had received* 1 *of* B; also $\overline{5 - 1} \times 2 = 7 + 1 = 8 =$ B's *parcel when he received* 1 *of* A.

—If a traveller leaves New York at 8 o'clock in the morning, and walks rds New London at the rate of 3 miles per hour, without intermission; another traveller starts from New London at 4 o'clock in the evening, walks towards New York at the rate of 4 miles per hour continuously; ming distance between the two cities to be 130 miles, whereabouts upon road will they meet?

RATION. —From 8 to 4 o'clock is 8 hours; therefore, $8 \times 3 = 24$ *miles, per- ed by* A *before* B *set out from New London;* and, consequently, $130 - 24 = 106$ *he miles to be travelled between them after that.*

nce, as $(3 + 4)\ 7 : 3 :: 106 : \frac{318}{7} = 45\frac{3}{7}$ *more miles travelled by* A *at the meeting;* equently, $24 + 45\frac{3}{7} = 69\frac{3}{7}$ *miles from New York is place of their meeting.*

—If from a cask of wine a tenth part is drawn out and then it is filled water; after which a tenth part of the mixture is drawn out; again led, and again a tenth part of the mixture is drawn out: now, assume luids to mix uniformly at each time the cask is replenished, what frac- l part of wine will remain after the process of drawing out and replen- g has been repeated four times?

ERATION.—Since .1 of the wine is drawn out at first drawing, *there must remain* After cask is filled with water, .1 of whole being drawn out, *there will remain mixture; but .9 of this mixture is wine;* therefore, after second drawing, *there remain .9 of .9 of wine,* or $\frac{9^2}{10^2}$; and after third drawing, *there will remain of .9 of wine,* or $\frac{9^3}{10^3}$.

nce, the part of wine remaining is expressed by the ratio .9, *rais ent of which is number of times cask has been drawn from.*

erefore, fractional part of wine is $\frac{9^4}{10^4} = .6561.$

4 E*

16.—There is a fish, the head of which is 9 ins. long, the tail as long as the head and half the body, and the body as long as both the head and tail. Required the length of the fish.

OPERATION.—Assume body to be 24 ins. in length. Then $24 \div 2 + 9 = 21$, *length of tail.*

Hence $21 + 9 = 30$, *length of body*, which is 6 ins. too great.

Again: assume the body to be 26 ins. in length. Then $26 \div 2 + 9 = 22$, *length of tail.* Hence $22 + 9 = 31$, *length of body*, which is 5 ins. too great.

Therefore, by *Double Position*, divide *difference* of products (see rule, page) by *difference* of errors (the errors being alike), $\overline{26 \times 6} - \overline{24 \times 5} = 36 =$ *difference of products*, and $6 - 5 = 1 =$ *difference of errors.*

Consequently, $36 \div 1 = 36$, *length of body*, and $36 \div 2 + 9 = 27$, *length of tail*, and $36 + 27 + 9 = 72$ *ins., length required.*

17.—A hare, 50 leaps before a greyhound, takes 4 leaps to the greyhound's 3, but 2 leaps of the hound are equal to 3 of the hare's. How many leaps must the greyhound take before he can catch the hare?

OPERATION.—As 2 leaps of the greyhound equal 3 of the hare, it follows that 6 of the greyhound equal 9 of the hare.

While the greyhound takes 6 leaps, the hare takes 8; therefore, while the hare takes 8, the greyhound gains upon her 1.

Hence, to gain 50 leaps, she must take $50 \times 8 = 400$ *leaps; but, while hare takes 400 leaps, greyhound takes* 300, *since number of leaps taken by them are as* 4 *to* 3.

18.—If a basket and 1000 eggs were laid in a right line 6 feet apart, and 10 men (designated from A to J) were to start from basket and to run alternately, collect the eggs singly, and place them in basket as collected, and each man to collect but 10 eggs in his turn, how many yards would each man run over, and what would be entire distance run over?

OPERATION.—A's course would be 6×2 *feet* (*first term*) $+ \overline{10 \times 6 \times 2}$ *feet* (*last term*) $= 132 =$ *sum of first and last terms of progression.*

Then $\overline{132 \div 2} \times 10 = 660$ *feet* $=$ *number of times* $\times$ *half sum of extremes* $=$ *sum of all the terms, or the distance run by* A *in his first turn.*

B's course would be $\overline{11 \times 6 \times 2} = 132$ *feet* (*first term*) $+ \overline{20 \times 6 \times 2} = 240$ *feet* (*last term*) $= 372 =$ *sum of first and last terms.*

Then $\overline{372 \div 2} \times 10 = 1860 =$ *sum of all the times, or* B'*s first turn.*

A's last course would be $\overline{901 \times 6 \times 2} = 10\,812$ *feet for the first term*, and $\overline{910 \times 6 \times 2}$ $= 10\,920$ *feet for the last term of his last turn.*

Then $\overline{10\,812 + 10\,920 \div 2} \times 10 = 108\,660 =$ *sum of the terms, or distance run.*

B's last course would be $\overline{911 \times 6 \times 2} = 10\,932$ *feet for the first term*, and $\overline{920 \times 6 \times 2}$ $= 11\,040$ *feet for the last term of his last turn.*

Then $\overline{10\,932 + 11\,040 \div 2} \times 10 = 109\,860 =$ *sum of the terms or distance run.*

Therefore, if A's first and last runs $= 660$ and $108\,660$ *feet*, and the number of terms 10, then, by *Progression*, the sum of all the terms $= 546\,600$ *feet.*

And if B's first and last runs $= 1860$ and $109\,860$ *feet*, and the number of terms 10, then the sum of all the terms $= 558\,600$ *feet.*

Consequently, $558\,600 - 546\,600 = 12\,000 =$ *common difference of runs*, which being added to each man's run $=$ sum of all runs, or entire distance run over.

A's *run*, $546\,600 = 182\,200$ *yds.*	F's *run*, $606\,600 = 202\,200$ *yds.*
B's " $558\,600 = 186\,200$ "	G's " $618\,600 = 206\,200$ "
C's " $570\,600 = 190\,200$ "	H's " $630\,600 = 210\,200$ "
D's " $582\,600 = 194\,200$ "	I's " $642\,600 = 214\,200$ "
E's " $594\,600 = 198\,200$ "	J's " $654\,600 = 218\,200$ "
	$6\,006\,000$ *feet*, which $\div 5280 = 1137.5$ miles.

19.—If, in a pair of scales, a body weighs 90 lbs. in one scale, and but 40 lbs. in the other, what is the true weight?

$$\sqrt{(40 \times 90)} = 60 \text{ lbs.}$$

—If a steamboat, running uniformly at the rate of 15 miles per hour gh the water, were to run for 1 hour with a current of 5 miles per hour, to return against that current, what length of time would she require ıch the place from whence she started?

:RATION. $15+5=20$ *miles, the distance run during the hour.*

n $15-5=10$ *miles is her effective velocity per hour when returning, and* ιo $=2$ *hours, the time of returning,* and $2+1=3$ *hours, or the whole time oc-* *l.*

Let d represent distance in one direction, t and t′ greater and less times of run- in hours, and c current or tide.

:n, $\dfrac{d\frac{t+t'}{2}}{t\times t'}=$ *velocity of boat through the water,* and $\dfrac{\overline{v\times t'}-d}{t'}=c.$

.—Flood-tide wave in a given river runs 20 miles per hour, current of 3 miles per hour. Assume the air to be quiescent, and a floating body ·ee at commencement of flow of the tide; how long will it drift in one tion, the tide flowing for 6 hours from each point of river?

:RATION.—Let x be the time required; $20x=$ distance the tide has run up, to- r with the distance which the floating body has moved; $3x=$ whole distance ι the body has floated.

n $20x-3x=6\times 20$, *or the length in miles of a tide.*

$$x=\frac{20}{20-3}\times 6=7 \textit{ hours, } 3 \textit{ minutes, } 31.765 \textit{ seconds.}$$

—A steamboat, running at the rate of 10 miles per hour through the ·, descends a river, the velocity of which is 4 miles per hour, and re- in 10 hours; how far did she proceed?

:RATION.—Let $x=$ distance required, $\dfrac{x}{10+4}=$ *time of going,* $\dfrac{x}{10-4}=$ *time of* *ıing.* Then, $\dfrac{x}{14}+\dfrac{x}{6}=10$; $6x+14x=840$; $20x=840$; $840\div 20=42$ *miles.*

—From Caldwell's to Newburgh (Hudson River) is 18 miles; the cur- of the river is such as to accelerate a boat descending, or retard one .ding, 1.5 miles per hour. Suppose two boats, running uniformly at the of 15 miles per hour through the water, were to start one from each at the same time, where will they meet?

:RATION.—Let $x=$ the distance from N. to the place of meeting; *its distance* C., *then, will be* $18-x$.

ed of descending boat, $15+1.5=16.5$ *miles per hour;* of ascending boat, $15-$ 13.5 *miles per hour.* $\dfrac{x}{16.5}=$ *time of boat descending to point of meeting.* $\dfrac{18-x}{13.5}$ *e of boat ascending to point of meeting.*

se times are of course equal; therefore, $\dfrac{x}{16.5}=\dfrac{18-x}{13.5}$. Then, $13.5x=297-$ and $13.5x+16.5x=297$, or $30x=297$.

ıce $x=\dfrac{297}{30}=9.9$ *miles, the distance from Newburgh.*

—There is an island 73 miles in circumference; 3 men start together .lk around it and in the same direction: A walks 5 miles per hour, B 8, C 10; when will they all come aside of each other again?

:RATION.—It is evident that A and C will be together every rou it remains to ascertain when A and B will be in conjunction at a niles are gained every day by B. Therefore, as $3:1::73:24$ ·njunction is a fractional number, it is necessary to ascertain wh tiplier will make the division a whole number.

$\div 24.33+=3$, *the number of days required in which A will go* *nd C 10 times.*

**25.—Assume a cow, at age of 2 years, to bring forth a cow-calf, :
to continue yearly to do the same, and every one of her produce :
forth a cow-calf at age of 2 years, and yearly afterward in like 1
how many would spring from the cow and her produce in 40 years?**

OPERATION.—The *increase* in 1st year would be 0, in 2d year 1, in 3d 1, in 5th 3, in 6th 5, and so on to 40 years or terms, *each term being = sum o preceding ones*. The last term, then, will be 165 580 141, from which is tc tracted 1 for the parent cow, and the remainder, 165 580 140, *will represent required.*

26.—The interior dimensions of a box are required to be in the tions of 2, 3, and 5, and to contain a volume of 1000 cube ins.; what be the dimensions?

OPERATION.—$\sqrt[3]{\frac{1000 \times 2^3}{2 \times 3 \times 5}} = 6.43$; $\sqrt[3]{\frac{1000 \times 3^3}{2 \times 3 \times 5}} = 9.65$; and $\sqrt[3]{\frac{1000 \times 5^3}{2 \times 3 \times 5}} =$

And what for a box of one half the volume, or 500 cube ins., and re same proportionate dimensions?

OPERATION.—$2 \times 3 \times 5 = 30$, and $\frac{30}{2} = 15$.

Then, $\sqrt[3]{\frac{15 \times 6.43^3}{30}} = 5.1$; $\sqrt[3]{\frac{15 \times 9.65^3}{30}} = 7.66$; and $\sqrt[3]{\frac{15 \times 16^3}{30}} = 12$

27.—The chances of events or games being equal, what are the od or against the following results?

Five Events.

Odds.	Against.	In favor.
31 to 1	All the 5	1 out of 5
4.33 to 1	4 out of 5	2 out of 5

5 to 3 in favor of the 5 events resulting 3 and 2.

Four Events.

Odds.	Against.	In fa'
15 to 1	All the 4	1 out
2.2 to 1	3 out of 4	2 out

5 to 3 against 2 events only, o the 4 events do not result 2 and 2.

Three Events.

Odds.	Against.	In favor.
7 to 1	All the 3	1 out of 3
Even	2 or all out of 3	2 or all out of 3

3 to 1 in favor of the 3 events resulting 2 and 1.

Two Events.

Odds.	Against.	In fa'
3 to 1	Both events	1 out
Even	1 only out of 2	1 onl of 2

Even that the events result 1 an

28.—Required the chances or probabilities in events or games, wh chances or probabilities of the results, or the players, are equal.

Events or Games.	That a *named* event occurs a majority or more of times.	Against a *named* event occurring an exact majority of times.	Against each event occurring an equal number of times.	Events or Games.	That a *named* event occurs a majority or more of times.	Against a *named* event occurring an exact majority of times.	Agai event ring num ti
21	Even	5 to 1	—	11	Even	3.4 to 1	
20	1.33 to 1	—	4.66 to 1	10	1.7 to 1	—	3.0
19	Even	4.5 to 1	—	9	Even	3 to 1	
18	1.55 to 1	—	4.4 to 1	8	1.75 to 1	—	2.6
17	Even	4.4 to 1	—	7	Even	2.7 to 1	
16	1.5 to 1	—	4.1 to 1	6	2 to 1	—	2.2
15	Even	4 to 1	—	5	Even	2.2 to 1	
14	1.5 to 1	—	3.8 to 1	4	2.2 to 1	—	1.6
13	Even	3.7 to 1	—	3	Even	1.66 to 1	
12	1.6 to 1	—	3.44 to 1	2	3 to 1	—	E

29.—The chances of consecutive events or results are as follows:

to 1. | 10.—1023 to 1. | 9.—511 to 1. | 8.—255 to 1. | 7.—127 to 1. | 6.—

-ill be observed that the chances increase with the number of duplicate ratio.

of 11 consecutive events compared with 10,

30.—Required the chances or probabilities of events or results in a given number of times.

The *numerator* of a fraction expresses the chance or probability either for the result or event to occur or fail, and the *denominator* all the chances or probabilities both for it to occur or fail.

Thus, in a given number of events or games, if the chances are even, the probability of any particular result is as $\frac{1}{1+1}=\frac{1}{2}$; $\frac{2}{2+2}$; $\frac{3}{3+3}$, etc., being 1 out of 2 out of 4, etc., or even.

If the number of events or games are 3, then the probability of any particular result, as 2 and 1, or 1 and 2, is determined as follows:

Number of permutations of 3 events are $1\times 2\times 3=6$, which represents number of times that number of events can occur, 2 and 1, or 1 and 2, to which is to be added the 2 times or chances they can occur all in one way or the reverse thereto.

Hence, $\frac{6}{2+6}=\frac{3}{4}=\frac{3}{4-3}=\frac{3}{1}$, or 3 to 1 in favor of result; and probability of the party naming or winning two precise events or results, as winning 2 out of 3, is determined as follows: Number of permutations and chances, as before shown, are 8. Hence, number of his chances being 3, $\frac{3}{3+5}=\frac{3}{8}=\frac{3}{8-3}=\frac{3}{5}$, or 3 to 5 in favor of result; and probability of one party naming or winning all, or 3 events or results, is determined as follows: Number of permutations and chances being so, as before shown, 8. Hence, as there is but one chance of such a result, $\frac{1}{1+7}=\frac{1}{8}=\frac{1}{8-1}=\frac{1}{7}$, or 1 to 7 in favor of result.

If number of events, etc., are 4, then probability of any particular result, as 2 and 2, or of winning 2 or more of them, is determined as follows:

Number of permutations and chances of 4 events are 16. Hence, as number of chances of such a result are 11, $\frac{11}{5+11}=\frac{11}{16}=\frac{11}{16-11}=\frac{11}{5}$, or as 11 to 5 in favor of the result, and that the results do not occur precisely 2 and 2. The number of chances of such a result being 10, $\frac{10}{6+10}=\frac{5}{8}=\frac{5}{8-5}=\frac{5}{3}$, or 5 to 3 against it.

If number of events, etc., are 5, then probability of any particular result, as 3 and 2, is determined as follows:

Number of permutations and chances being 32, and number of chances of such result being 20, $\frac{20}{12+20}=\frac{10}{16}=\frac{10}{16-10}=\frac{10}{6}=\frac{5}{3}$, or as 5 to 3 in favor of the result; and that it may occur precisely 3 out of 5, the number of chances are $\frac{10}{10+22}=\frac{10}{32}=\frac{5}{16}=\frac{5}{16-5}=\frac{5}{11}$, or 11 to 5 against it.

31.—What is the dilatation of the iron in a railway track per mile, between the temperatures of $-20°$ and $+130°$?

OPERATION.— $-20°+130°=150°$. The dilatation of wrought iron (as per table, page 519) is, from 32° to 212° = 180° = .001 257 5 times its length.

Hence, as 180 : 150 :: .001 257 5 : .001 047 9 = $\frac{.001\,047\,9}{1}$ of 5280 (feet in a mile) = 53 *feet per mile.*

32.—A steamer having an immersed amidship section of 125 sq. feet, has speed of 15 miles per hour with 300 IP. What power would be r one of like model, having a section of 150 sq. feet for a speed of

As power required for like models is as cube of speeds.

Then $\frac{150}{125}=1.2$ *relative sections*, and $\frac{20^3=8000}{15^3=3375}=2.37$ *relative p*

Hence, 1 : 1.2 :: 2.37 : 2.844 *times* IP.

ELEMENTS AND CAPACITIES OF NAVAL MARINE STEAMERS.

Cruisers. Iron-clad and Protected.

Compound, Triple, and Quadruple Expansion.

…rpendiculars and Hull, in feet and ins.; Engines and Propeller, in feet and ins; Revolutions, per minute; Surfaces, in sq. feet; Pressure, in pounds, and Weights and Displacements, in tons of 2240 lbs.

Speed in Knots per Hour.

American.

…ENSIONS AND …APACITIES.	Cushing.*	Maine.	Charleston.	Yorktown.	Chicago.	Baltimore.	Vesuvius.†	Philadelphia.	Newark.	‡	San Francisco.
Construction	Unarm'd Steel.	Iron-clad.	Prot'd Cruiser.	Gun-boat.	Prot'd Cruiser.	Prot'd Cruiser.	Unarm. Steel.	Prot'd Steel.	Prot'd Steel.	Prot'd Cruiser.	Prot'd Cruiser.
Length	137.5	310	300	228	315	315	246.25	315	310	400	310
Beam	14.1	57	46.2	36	48.3	48.6	26.6	48.7	48.1	58	49.2
Hold	—	—	—	18.9	34.9	—	14.1	—	31.8	—	28.8
Draught, medium	4.5	21.6	17.10	14	19.1	19.10	9.3	19.2	18.9	23	18.9
Displacement at do. do.	91.34	6648	3557	1703	4536	4500	805	4325	4083	7400	4088
Immersed Sec'n at do.	42.36	1080	712	435	—	833	—	815	807	—	770
Cylinders, HP	11.25	35.5	44.125	22	45	42	21.5	38	34	42	42
" Int	22.5	57	—	31	—	60	31	58	52	59	60
" LP	3 of 22.5	88	85.25	50	78	94	2 of 34	86	76	92	94
Stroke of Piston	15	36	36	30	57	42	20	40	40	42	36
Steam, Pressure of	245	135	91.5	157	85	133	157	153	160	160	135
Revolutions	370	133	114.65	160.8	70	116.25	269	119.6	127	129	124.8
Grate Surface	76.5	553	436.2	220	672	676	195	624	561.4	1288	568
Heating "	4750	18 800	15 577	8092	21 306	17 175	8981	20 458	17 295	43 272	20 134
Condensing "	1052	14 020	13 796	4760	9174	12 369	4518	13 510	12 510	18 948	14 518
Propeller, diam	2 of 4.3	2 of 14	2 of 14	2 of 10.5	2 of 15.6	2 of 14.5	2 of 7.9	2 of 14.6	2 of 14.6	3 of —	2 of 13.6
" pitch	8.5	17.5	17.6	12.5	24.54	21.6	9.4	20.5	19	—	18.9
Coal, weight	25	400	328	200	940	400	150	400	400	750	400
Speed	22.5	17	18.2	16.65	15.33	19.84	21.42	19.68	19	22	19.52
IHP	1720	9000	6666	3660	4606	10 064	3795	8815	8868	23 000	9913
Combustion	Blast	Blast	Blast	Blast	Natur'l	Blast	Blast	Blast	Blast	Blast	Blast

English.

…ENSIONS AND …APACITIES.	Medea and Class.	Benbow and Class.	Trafalgar and Nile.	Archer.	Rattlesnake and Class.
Construction	Prot'd Cruiser.	Iron-clad.	Iron-clad.	Unarm. Steel.	Unarm. Steel.
Length	265	325	345	225	200
Beam	41	68	73	36	23
Hold	—	—	—	—	—
Draught, medium	16.6	26.4	27.6	13.6	8.33
Displacement at do. do.	2800	9500	11 940	1630	475
Immersed Sec'n at do.	—	—	—	—	
Cylinders, HP	33.5	52	43	27	18.5
" Int	47	—	62	—	27
" LP	74	2 of 74	96	50	42
Stroke of Piston	39	45	51	33	18
Steam, Pressure of	149	89.2	134	127	136
Revolutions	143.3	101.5	95	157	309.5
Grate Surface	456	756	604	224	122
Heating "	14 070	20 294	19 390	5900	5000
Condensing "	11 850	17 000	15 000	5640	4000
Propeller, diam	2 of 13.5	2 of 18.6	2 of 16.6	2 of —	2 of 6.6
" pitch	17.3	17.5	21.3	—	7.6
Coal, weight	400	1200	900	250	100
Speed	19.6	17.5	17.3	17.2	18.78
IHP	9975	10 852	12 818	3982	2718
Combustion	Blast	Blast	Blast	Blast	Blast

* Torpedo-boat. † Dynamite Gun-boat. ‡ Not named.

Compound and Triple Expansion.

Length, between perpendiculars and Hull, in feet and ins.; Engines and Propeller, in feet and ins; Revolutions, per minute; Surfaces, in sq. feet; Pressure, in pounds, and Weights and Displacements, in tons of 2240 lbs.

Speed in Knots per Hour.

Dimensions and Capacities.	English. Sunderland.*	English. Galatea.	French. Cécille.	French. Forbin.	Italian. Piemonte.	Italian. Lepanto.	Italian. Nibbio.*	Italian. Tripoli.	Spanish. Destructor.	Spanish. Reina Regente.	Spanish. Ariete.	Austrian. Falke.	Brazilian. Riachuelo.	Chilian. Esmeralda.	Chilian. Almirante Condel.	Japan. Naniwa.
Construction	Unarm'd Steel.	Belted Cruiser.	Prot'd Cruiser.	Prot'd Cruiser.	Prot'd Cruiser.	Iron-clad.	Unarm. Steel.	Unarm. Steel.	Unarm. Steel.	Prot'd Cruiser.	Torpedo.	Torpedo.	Iron-clad.	Prot'd Cruiser.	Torpedo.	Prot'd Cruiser.
Length	137	300	378.9	311.7	300	400.5	151.8	229.6	192.5	320	147.5	135	305	270	240	300
Beam	13.9	56	49.3	30.6	38	72.9	17	25.7	25	50.6	14.5	13.75	52	45	27.6	46.16
Hold	—	—	—	—	—	—	—	18.31	—	31.6	—	—	—	—	—	—
Draught, medium	4	21	19.8	13.11	15	30.4	—	—	6.6	20	3.33	4.25	19.6	18.6	9	18.6
Displacement at do. do.	84	5040	5766	1848	2500	14 860	145	—	385	4800	97	87	5700	3000	710	3730
Immersed Sec'n at do.	40	—	8375	—	3409	1999	—	—	—	—	—		—	—	—	—
Cylinder, HP	15	36	39	36.8	36	—	17	19.5	18.5	40	14.5	18	52	43	22	44
" Int.	22	51	—	—	55	—	26	—	27	60	—	—	—	—	33	—
" LP.	33.5	77	72	73.6	2 of 60	54	37	35	42	92	24.5	2 of 26	2 of 74	82	49	85
Stroke of Piston	18	44	38	36	27	39	17	16	21	45	15	18	36	36	21	36
Steam, Pressure of	160	138	—	100	—	49	195	130	145	140	139	143	90	90	143	88.5
Revolutions	352	113.5	85.8	140	—	93.5	325	297	292	116	375	355	81.5	116.5	270	121.4
Grate Surface	—	500	852	291	—	1153.5	—	168	144	658	75.4	44	585	450	190	392
Heating "	2174	15 900	23 919	14 100	—	42 080	3400	6696	5920	22 500	4240	2000	19 400	15 256	6000	15 114
Condensing Surface	1745	12 000	15 494	—	—	31 360	—	—	5000	15 000	—	—	12 000	—	—	13 500
Propellers, diam.	6	2 of —	2 of —	2 of 13.2	2 of —	2 of 20.6	2 of 5.11	3 of 5.9	2 of 7.3	2 of —	2 of —	—	2 of —	2 of 14.6	2 of 8	—
" pitch	8.3	23.3	—	17.1	—	20.6	—	7.1	9.2	—	—	—	—	18	9	—
Coal, weight	Oil	440	650	200	200	1858	14	100	45	500	—	—	—	400	—	—
S	21	19	16.49	20.6	22	18.38	26.8	19.8	22.68	20.6	24.9	22.3	15.3	18.28	20.3	18.9
...	1204	9203	6348	5000	12 700	16 150	2200	3016	3829	12 000	1500	1400	4537	6750	4350	7650
..	Blast	Blast	Blast	Blast	Blast	Blast	Blast	Blast.	Blast	Blast	Blast	Blast	Blast	Blast	Blast	Blast

* Torpedo-boats.

Passenger and

Compound and Triple

Lengths and Hull, in feet and tenths; Draught, Propeller, and Side Wheels in feet a...

Surfaces, in sq. feet; Weights and Displacements, in Tons of 2240 lbs.; Fuel, in ...

Speed in Knots per Hour.

DIMENSIONS AND CAPACITIES.	City of Paris and New York.	Columbia.	Nairnshire.	Bremerhaven.	Tynesider.	Simon Dumois and Managua.	Electric and Frolic.	El Sol.
	1. Steel.	2. Steel.	3. Steel.	4. Steel.	5. Iron.	6. Steel.	7. Iron.	8. Iron.
Service	P and F	P and F	Refrig'tor	Petroleum	F and P	Fruit	Fishing	F and P
Length on deck	527.6	474	350.5	350	260.5	184	111.9	388.75
" bet. perp'rs	525	463	350	340	260	174.8	106.9	377.1
" tonnage	527.6	463.5	350.6	339.6	260	175.2	107.4	375
Beam, do.	63.2	55.6	47.7	42.6	33.7	27.8	20.5	48
Hold, do.	22	35.8	24.2	27.3	15.2	19	11.5	24
Decks	4	4	2	2	2	2	1	3
Tons {	5 581	3737	2428	2179	692	514	79	3011
Tons {	10 499	7363	3720	3393	1290	717	183	—
Draught, load	25	24	24.3	21.3	17.4	16.2	11.5	21
Displacement do.	—	10 000	7880	6600	2560	1462	230	6700
Imm'd Sec'n at do.	—	—	1058	870	530	404	135	934
Freeboard	—	14.7	4	5	1.9	4.5	—	13
Cylinders, HP	2 of 45	2 of 41	27	25	28.5	16	12.75	32
" Int.	2 " 71	2 " 66	44	40	46	26	20	52
" L. P.	2 " 113	2 " 101	71	66	75	40	32	84
Stroke of piston	60	66	48	42	42	33	22	54
Steam pressure	150	150	160	160	160	160	150	160
Revolutions	86.5	74	70	62	74	90	134	76
Boilers	9	9	3	2	3	1	1	3
Grate surface	1293	1220	209	154	216	63	29	447
Heating do.	50 625	35 000	6963	4800	6618	2010	800	10 500
Condensing do.	33 000	—	3032	2383	3450	—	390	6400
Propeller, diam.	—	2 of 18	16.5	17.6	16	10	7.9	18
Pitch	—	32	18.5	17.6	21	14.5	8.6	23
Side wheels, diam.	—	—	—	—	—	—	—	—
Breadth	—	—	—	—	—	—	—	—
Coal, weight	—	—	1266	821	130	143	—	1000
Consumption	3300	—	3000	—	2400	1005	—	5000
Combustion	Blast	Natural	Natural	Natural	Natural	Natural	Natural	N and B
Cargo	—	—	5360	4000	1080	936	—	4000
Passengers	1372	1096	50	—	1389	16	—	—
Crew	395	—	48	25	25	20	12	50
IHP	19 175	13 000	2000	1550	2400	670	388	3500
Speed	20	20	11.5	10	15.1	12.5	10.25	14.5
Rig	Bark'ne	3-m Sch'r	Brig	3-m Sch'r	3-m Sch	Sch'r	Dandy	4-m Sch

Remarks.——No. **1.** J. & G. Thomson, Glasgow, Scotland; Area of Immersed
...rizontal Section at Load-line, 16 500 □ feet = coefficient .5.———No. **2.** Laird
...rkenhead, Eng.———No. **3.** R. & W. Hawthorn, Leslie & Co., New-
Hull 2375 tons, Engines 180, and Boilers 156.———No. **4.** Russell
...wart & Co., Greenock, Eng.; Hull 1950 tons, Engines and Boilers
5. Tyne Steam Shipping Co., Newcastle, England; Engines 135
...d Water 60, "Well-deck."———No. **6.** Grangemouth Dock
...asgow, Scotland; Hull 391 tons, Engines 52, Boilers
...ne 3850 □ feet, and of Sails 2310.———No. **7.**
... The Wm. Cramp & Sons S. and E. B. Co., Phila.
..., Delaware River I. S. B. and E. Co., Chester.

Freight.

Expansion.

nd ins.; Engines, in ins.; Pressure, in lbs.; Revolutions, per minute; lbs. per Hour; P *Passengers and* F *Freight.*

Speed in Miles per Hour.

Puritan.	Tuscarora.	City of Racine.	John F. Smith.	New York.	Atalanta.	Susquehanna.	Robert E. Lee.	Maryland.
10.	**11.**	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**
Steel.	Steel.	Iron.	Iron.	Iron.	Iron.	Iron.	Wood.	Steel.
P and F	F	F and P	P and F	P	Yacht	Yacht	P and F	F and P
—	306.7	220	130	315	240	166.5	315	332
402	296.7	—	122	—	228.5	150	306	—
403.5	289.3	203.5	122	301	222.9	164	315.8	316.4
52	40	35	42	40.2	26.33	22	48.5	42
18.1	23	—	9	11	15.2	13	9.2	20.4
1	2	1	1	1	2	1	1	2
3075	1937	802	142.39	1092	284	117	—	1892
4593	2669	1041	135.60	1553	568	233	1479	2419
13	16	—	5.3	6.33	12	9.3	—	16
4775	3570	—	155	1000	1042	310	—	4690
643	624	218	83	235	246	128	—	650
7	9.7	—	3	6	4.75	4.5	—	8
75	24	28	14	—	30	17	2 of 40.5	22
—	38	—	—	—	—	28	—	35
110	61	50	26	75	60	42	—	56
and 14	42	36	18	12	30	22	10	44
110	160	110	125	50	115	160	148	160
24	90	100	—	30	128	164	21	85
8	3	2	1	3	2	1	9	2
850	162	90	—	230	146	65	118	152
26000	5574	4000	1258	5360	4534	2180	3360	4656
15000	Jet	—	624	5700	2226	1470	—	—
—	14	10.5	6.4	—	—	8	—	13.2
—	17.5	16.5	9	—	—	—	—	16
35	—	—	—	30.16	—	—	39	—
14	—	—	—	12.5	—	—	17	—
200	230	110	15	50	170	50	—	200
9 p. HP	2340	1400	4	2.5 p. HP	—	—	—	—
Natural	Natural	Natural	Natural	Blast	Blast	Blast	Natural	Natural
900	2140	310	—	—	—	—	1425	3100
1200	—	—	150	2100	18	—	300	8
200	29	—	8	50	45	—	150	19
7500	1800	750	300	3700	1950	925	—	1200
21	16	14.5	13	23	17.45	18	21	12.5
—	Sch'r	Sch'r	—	—	3-m Sch'r	Sch'r	—	

nd W. and A. Fletcher Co., Hoboken, N. J.———No. **11.** Cleveland, Ohio; Hull 1240 tons, Engines 200, and Boilers 70 t Chas. F. Elmes, Chicago, Ill., and Burger & Burger, Wis.; deck; Hull 350 tons, Engines 40, Boilers 36, and Water 23.— ey & Jones Co., Wilmington, Del.———No. **14.** W. & A. Fle , N. J.; Water-wheel blades, 13 of 45 ins.———No. **15.** San .———No. **16.** The Harlan & Hollingworth Co., Wilmington, , Engines 20, and Boilers 25.———No. **17.** Jas. Howard & lle and American Foundry, New Albany, Ind.; Water-wheel s ———*No.* **18.** Detroit Dry Dock Co., Detroit, Mich.; Hull *140, and Boilers 70.*

Ferry Passenger and Team, and Tow-boats. Single, Compound, and Triple Expansion.

Length and Hull, in feet and tenths; Draught, Propeller, and Side Wheels, in feet and ins.; Engines, in ins.; Pressure, in lbs.; Revolutions, per minute; Surfaces in sq. feet; Weights and Displacements, in Tons of 2240 lbs.; Fuel, in lbs. per Hour; P Passengers and T Teams.

Speed in Miles per Hour.

Dimensions and Capacities.	[illegible] and Whitehall Ferry.	John G. McCullough Ferry.	Bergen Ferry.	Intrepid.	Maine Ferry.	[illegible]	[illegible]
	1. Iron.	2. Steel.	3. Steel.	4. Iron.	5. Iron.	6. Iron.	7. Iron.
Service	P and T	T and P	P and T	Towing	T and P	Towing	Towing
Length on deck	209	215	203	118	189.2	140	95
" bet. perp'rs	195	198.5	200	110	175	129.6	87.66
" tonnage	196	198.5	220.4	114	174	130	92.5
Beam do.	37.4	45	37	23.5	36.5	26	18.5
" over guards	65	62	62	—	62.5	—	—
Hold, tonnage	14.1	14.5	16.6	11.6	13.3	16.2	8.6
Decks	1	1	1	1	1	1	1
Tons {	839	1008	734	108.9	545.7	400	55.6
Tons {	1088	1310	1117	217.8	850.3	200	95.6
Draught, load	9	11	9.5	9.5	7.2	12	8
Displacement do.	880	1340	560	303	678.5	530	150
Immersed Sec'n at do.	215	450	225	164	206	260	—
Freeboard	7.5	7.75	6.9	4	5 & 6.5	5.5	—
Cylinders, HP	—	22	18.5	22	46	16	15
" Int.	—	50	27	—	—	24	—
" L.P.	50	—	42	40	—	41	32
Stroke of Piston	10	36	24	26	120	30	28
Steam Pressure	50	100	160	100	22	160	100
Revolutions	32	120	162	90	24	—	100
Boilers	1	2	2	1	1	2	1
Grate surface	168	140	81	71.5	76	80	45.5
Heating do.	1380	—	3462	2503	2259	2400	1318
Condensing do.	Jet	—	—	1105	Jet	1100	553
Propeller, diam. {	—	2 of	2 of 8	9.5	—	9.5	8
Propeller, diam. {	—	—	—	—	—	—	—
Pitch	—	—	8.91	14 & 16	—	—	14
Blades	—	4	4	4	—	4	4
Side-wheel diam.	20.5	—	—	—	20.5	—	—
" width	8.66	—	—	—	8.6	—	—
Coal, weight	5	—	15	60	40	270	16
Consumption	—	—	1580	—	—	—	420
Combustion	Natural	Natural	Natural	Natural	Natural	Natural	Natural
IHP	1010	—	1007	—	650	800	250
Team space	3500	4530	3448	—	3420	—	—
Passenger do.	4130	5200	4330	450	2896	—	—
Weight, Hull	470	—	321	—	—	—	[illegible]
Engine	104	—	177	13	12	—	[illegible]
Boilers	51	—	48.5	20.5	39.75	—	[illegible]
Water	29.5	—	25	17.6	29.6	—	—
Speed	12	12	14.6	13.5	12	15	[illegible]

Remarks.—No. 1. Side-wheel, T. S. Marvel & Co., Newburgh, and [illegible] Iron Works, N. Y.; Double ends.——No. 2. Neafie and Levy, Penn [illegible] Phila., Pa.; Propeller at each end.——No. 3. Hull same as 1. and [illegible] Iron Works, N. Y.; Propeller at each end; Weights: of Hull as launched; Engine including steering and ventilating; donkey pumps, piping and chimney; [illegible] surface, 1524 □ feet.——Nos. 4. and 5. The Harlan and Hollingsworth [illegible] Wilmington, Del., Propeller and Side-wheel.——No. 6. Neafie and Levy [illegible] one Wrecking pump, 16 and 20 × 18 ins., three 8-inch suctions on each [illegible] 400 tons water per hour; one fire-pump, eight 2.5-inch streams; [illegible] lights, 6000 candle power, several of 2000 candle arc-lights.——[illegible] No. 8. Hull same as No. [illegible] Pusey & Jones Co., Wilmington, Del.——[illegible] N. J.; Propeller at each end; engines W. & A. Fletcher Co., Hoboken, N. J.; [illegible] Stevens, Hoboken, N. J. Those * designed by Col. E. A. Stevens.

Wood Propellers.

.RESHOFF, R. N., VERTICAL DIRECT ENGINE (*Compound*).—*Length on deck*, 46 *over all*, 48 *feet; beam*, 9 *feet; hold*, 5 *feet*.

ɔlacement at load-line, 7.44 *tons*. *Area of section at load-line*, 217.8 *sq. feet*. *ɔf wetted surface*, 365.5 *sq. feet*. *Coefficient of fineness*, .396.

nder.—8 and 14 ins. in diam. by 9 ins. stroke of piston.

denser, External.—Surface.

peller.—4 blades, 3 feet in diam. by 4 feet 1 inch pitch.

ver, 42 ins. in diam.

'er (vertical coil). *Heating surface*, 174 sq. feet. *Grates*, 12.5 sq. feet.

ssure of Steam, 53 lbs. per sq. inch. *Revolutions*, 333 per minute. IHP, 68.4. 10.18 knots per hour. With 129 lbs. and 466 revolutions, 14.26 knots. IHP, *Weight of Engines, Boiler, and Water*, 5300 lbs.

:RESHOFF, VERTICAL DIRECT ENGINE (*Compound*).—*Length over all*, 86 *feet*; 11 *feet*. *Displacement*, 27 *tons*.

'nder.—13 and 22 ins. in diam. by 12 ins. stroke of piston.

face Condensing.

ssure, 130 lbs. per sq. inch.

ɔlutions, 460 per minute. *Speed*, 20 knots per hour. IHP, 425.

peller, 3 blades. *Pitch*, 5 feet.

.RESHOFF, R. I. N.—VERTICAL DIRECT ENGINE (*Compound*).—*Length over all*, ; *beam*, 7 *feet; hold*, 5.5 *feet*. *Displacement at load-draught of* 32 *ins.*, 7 *tons* bs.).

'nders.—8 and 14 ins. in diam. by 9 ins. stroke of piston. *Surface condenser.*

ssure of Steam.—140 lbs. per sq. inch, cut off at .5.

ɔlutions, 600 per minute. *Speed*, 19.875 knots per hour.

Cable or Rope Towing.

ɪITRA."—HORIZONTAL DIRECT ENGINES (*Condensing*).—*Length of boat*, 138 *feet*; 24.5 *feet; hold*, 7.5 *feet*.

ɪersed section, 74.4 *sq. feet*. *Displacement*, 200 *tons at load-line of* 3.75 *feet*. *·sed section*, 263.7 *sq. feet*. *Displacement*, 949 *tons*. *Tow.*—3 barges.

'nders.—2 of 14.18 ins. in diam. by 23.625 ins. stroke of piston.

net effective, 100. *Speed*, 7.73 miles per hour.

pellers.—Twin, 4 feet 2 ins. in diam.

ss.—Cable, 7485 lbs. Per ton of displacement, 6.5 lbs.; per sq. foot of im- d section, 22 lbs.

l.—Per mile and ton of displacement (1149), .078 lbs.

Towing. Wood Side Wheels.

M. H. WEBB."—HARBOR AND COAST.—VERTICAL BEAM ENGINES (*Condensing*). *gth upon deck*, 185.5 *feet; beam*, 30.25 *feet; hold*, 10.8 *feet*.

ɪersed Section at load-line, 194 *sq. feet*. *Displacement* 498.25 *tons, at load- ht of* 7.25 *feet*.

nders.—2, of 44 ins. in diam. by 10 feet stroke of piston; volume, 211 cube feet *nsers.*—*Jet*, 2, volume 105 cube feet. *Air-pumps.*—2, volume 45 cube fe

'er-wheels.—Diam., 30 feet. *Blades* (divided), 21; breadth of do., 4.6 of do., 2.33 feet. *Dip* at load-line, 3.75 feet.

ers.—2 (return flue). *Heating surface*, 3280 sq. feet. *Grates*, 147.5 sq. f

ke-pipe.—Area, 11.6 sq. feet, and 35 feet in height above the grate level.

ssure of Steam.—35 lbs. per sq. inch, cut off at .5 stroke. *Revolutions*, 2 e. IHP, 1500.

l.—**Anthracite or Bituminous.** *Consumption*, 1680 lbs. per hour.

d.—20 miles per hour.

its.—Engines, Wheels, Frame, and Boilers, 310 579 lbs.

Wood Side Wheels.

Passenger.

"MARY POWELL," HUDSON RIVER.—VERTICAL BEAM ENGINE (*Condensing*).—*Length on water-line*, 286 *feet; over all*, 294 *feet; beam*, 34 *feet* 3 *ins.; over all*, 64 *feet; hold*, 9 *feet. Deck to promenade deck*, 10 *feet.*

Immersed section at load-line of 6 *feet*, 200 *sq. feet. Displacement*, 800 *tons at mean load-draught of* 6 *feet.*

Area of transverse head surface of hull above water, 2000 *sq. feet.*

Cylinder.—72 ins. in diam. by 12 feet stroke of piston; volume, 338 cube feet. *Clearance* at each end, 12.5 cube feet.

Steam and Exhaust Valves, 14.75 ins. in diam. *Air-pump*, 40 ins. in diam. by 5 feet 2 ins. stroke of piston. *Condenser.—Jet*, 128 cube feet. *Crank-pin*, 8.75 ins. in diam. × 10.75 ins.

Beam, 22.5 feet in length; centre, 9.75 in diam.

Water-wheels.—Diam. 31 feet; blades (divided), 26; breadth of do., 10 feet 6 ins.; width, 1 foot 6 ins.; immersion, 3 feet 6 ins. *Shafts.*—Journal, 15.625 ins. by 17 ins.

Boilers.—2 (flue and return tubular), of steel, 11 feet front by 26 feet in length; shell, 10 feet in diam. and 16 feet 1 inch in length. *Furnaces*, 2 in each, of 4 feet 10 ins. by 8 feet in length. *Heating Surface*, 2660 sq. feet; and *Superheating*, 340 sq. feet in each. *Grates*, 152 sq. feet. *Flues*, 10 in each, transverse area, 11 feet 7 ins. *Tubes*, 80 in each, 4.5 ins. in diam., 6 feet 6 ins. in length, and 8 feet 7 ins. in transverse area.

Steam Chimneys, 8 feet in diam. × 12 feet in height. *Smoke-pipe*, 4 feet 6 ins. in diam. and 68 feet in height from grates.

Combustion, Blast. Blowers, 4 feet in diam. and 3 feet in width. *Revolutions*, 78 per minute. *Fuel* (anthracite), 6280 lbs. per hour, or 40 lbs. per sq. foot of grate per hour. Per sq. foot of heating surface, 2.25 lbs.

Speed, 23.65 miles per hour.

Pressure of Steam, 28 lbs. per sq. inch, cut off at .47 stroke; terminal pressure, 16.4 lbs.; throttle, .625 open. *Vacuum*, 25 ins. *Revolutions*, 22.75 per minute.

Temperatures.—Reservoir, 120°. *Feed water*, 120°. *Chimney*, 740°. IP.—Total, 1900. IHP, 1560. Net, 1450.

Evaporation.—Water per lb. of coal, from 120°, 7 lbs.; per lb. of combustible, from 120°, 8.2 lbs. *Steam* per total IP per hour, 21.1 lbs. *Coal* per do. do., 3.14 lbs.

Weights. Engine.—Frame, keelson, out-board wheel-frames donkey engine, and boiler, blower engines and blowers, all complete, 360 000 lbs. *Boilers.*—Iron return flue, 120 000 lbs. Steel return tubular, 116 000 lbs. Water, 128 000 lbs.

Capacity.—2000 passengers and their baggage.

Memoranda.—This vessel was originally but 266 feet in length, and when lengthened the cylinder of 62 ins. in diam. was removed and replaced with one of 72 ins. Engine designed throughout for original cylinder and a pressure of from 50 to 55 lbs., cutting off at .625 of stroke, with throttle wide open.

Engines and Boilers built by Fletcher, Harrison, & Co., New York, 1861 and 1875.

Iron Stern Wheels.

Passenger and Freight.

HORIZONTAL ENGINES (*Non-condensing*).—*Length upon deck*, 110 *feet; beam*, 14 *feet* (*deck projecting over*, 4 *feet*); *hold*, 3.5 *feet.*

Immersed section at load-line, 10.25 *sq. feet. Displacement at load-draught of* 1.1 *tons.*

—Two, of 10 ins. in diam. by 3 feet stroke of piston; volume of piston be feet.

iam. 13 feet. *Blades*, 13; breadth of do., 8.5 feet; depth of do., 8 ins.

, 33 per minute. *Boiler.*—One (horizontal tubular). *Tubes*, 100 of 2

Consumption, 4480 lbs. in 24 hours.

3; bilges, No. 4; bottom, No. 5; sides, Nos. 6 and 7
, ins. apart from centres.

Wood Stern Wheels.

Passenger and Deck Freight.

ONTANA."—HORIZONTAL ENGINES (*Non-condensing*).—*Length upon deck (over* 48 *feet; at water-line*, 245 *feet; beam*, 48 *feet* 8 *ins.* (*over all*, 50 *feet* 4 *ins.*)*;* *feet; draught of water at load-line*, 5.5 *feet.*

iersed section at load-line, 244 *sq. feet. Displacement at mean light draught* *ns.*, 594 *tons* (2000 *lbs.*)

nders.—Two, 18 ins. in diam. by 7 feet stroke of piston.

ves, 4.5 and 5 ins. in diam. *Piston-rod*, 4 ins. *Steam-pipe*, 4.5 ins. *Connect-d*, 30 feet in length.

ter-wheel, 19 feet in diam. by 35 feet face; blades, 3 feet in depth. *Shaft*, ins. in diam.

'ers.—Four (horizontal tubular), 42 ins. in diam. by 26 feet in length. Two in each, 15 ins. in diam. *Heating surface*, effective, 1023, total 1431 sq. feet. *ice*, 6.5 × 17 feet. *Grates*, 4.16 × 17 feet; surface, 70.8 sq. feet. *Smoke-pipes.* , 3 feet in diam. by 55 feet 3 ins. in height. *Exhaust or Blower draught.*

orimeter.—Of Bridge, 15.27; of Flues, 9.82; and of Chimneys, 14.14 sq. feet. of grate, compared to calorimeter of flues, 7.2; to ditto. of chimneys, 5; and dge, 4.6 sq. feet.

im-room, 562; and water space, 294 cube feet.

ll.—Frames, 4 × 6 ins. and 15 ins. apart at centres. Intermediate do., 4 × 6 nd running for 7.5 feet each side of keelson. *Planking.*—Bottom, oak, 4 ins.; o., 2.5 to 4 ins. *Deck beams*, pine, 3 × 6 ins. *Deck plank*, 2.5 ins. *Keelson*, *side do.*, eight each side, one each 7, 8.75, and 9 ins., and five 6.75 ins. *Wales*, ich side, 9 and 7 ins. by 3, and one 10 × 2.5 ins. *Deck posts*, 3.5 × 3 ins. and 4 part. *Deck beams*, 5.5 × 3 ins. *Knuckles*, oak, 6 × 12 ins. *Bulkheads*, one udinal and one athwartship at shear of stern. *Sheathing* of wrought iron, to .125 inch from just below light to load-line.

Posts.—White pine, 8.5 and 11 ins. square. *Chains*, 1.5 ins. in diam.

ights.—Boilers, 29 264; water, 18 351; and boilers, chimneys, grates, and water, lbs. Hull, oak, 520 560; Pine, 91 437; Bolts, spikes, etc., 8000, and Deck and s, 76 000 lbs.; Hull alone, 310 tons.

ight of hull compared to one of iron as 8 to 5, effecting a difference of about ns.

ITTSBURGH." — HORIZONTAL ENGINES (*Non-condensing*).—*Length on deck*, 252 *beam*, 39 *feet; hold*, 6 *feet; draught of water at load-line*, 2 *feet.*

nersed section at load-line, 75 *sq. feet. Displacement at load-draught of* 2 *feet*, *ns* (2000 lbs.).

inders.—Two, 21 ins. in diam. by 7 feet stroke of piston.

ter-wheel.—21 feet in diam. by 28 feet face.

'lers.—2 (horizontal tubular), 47 ins. in diam. by 28 feet in length. Two fires ch.

Oil Engine Launch.

lements of Engine and Dimensions of Launch.

Consumption .9 pint ordinary Mineral Oil per IHP per

IP*	Launch. Length.	Launch. Breadth.	Weight.†	Type.	HP*	L Length.
No.	Feet.	Feet.	Lbs.	No.	No.	Feet.
1	16	4	896	3	5	30
2	21	5	1332	2	10	40
3	27	6	1568	1	15	45

* Developed by Brake. † Of engine without oi

Passenger and Deck Freight.

"Pittsburgh."—Horizontal Engines (Non-condensing).—*Length on deck* [illegible] *feet; beam,* 35 *feet; hold,* 6 *feet; draught of water at load-line,* 2 *feet.*

Immersed section at load-line, 75 *sq. feet. Displacement at load-draught of* [illegible] 380 *tons* (2000 lbs.).

Cylinders.—Two, 22 ins. in diam. by 7 feet stroke of piston.

Water-wheel.—22 feet in diam. by 28 feet face.

Boilers.—2 (horizontal tubular), 47 ins. in diam. by 28 feet in length. Two flues in each.

Iron Stern Wheels.

Horizontal Engines (Non-condensing).—*Length upon deck,* 120 *feet; beam,* [illegible] *feet (deck projecting over,* 4 *feet); hold,* 3.5 *feet.*

Immersed section at load-line, 10.25 *sq. feet. Displacement at load-draught of* [illegible] *feet,* 33 *tons.*

Cylinders.—Two, of 10 ins. in diam. by 3 feet stroke of piston; volume of piston space, 1.6 cube feet.

Wheel.—Diam. 13 feet. *Blades,* 13; breadth of do., 8.5 feet; *depth of do.,* 1 [illegible]

Revolutions, 33 per minute. *Boiler.*—One (horizontal tubular). *Tubes,* 10 [illegible] ins. in diam.

Fuel.—Bituminous coal. *Consumption,* 4480 lbs. in 24 hours.

Hull.—*Plates,* keel, No. 3; bilges, No. 4; bottom, No. 5; sides, Nos. 6 and [illegible] *Frames,* 2.5 × .5 ins., and 20 ins. apart from centres.

Steel.

"Chattahoochee."—Inclined Engines (Non-condensing).—*Length on deck,* [illegible] *feet; beam,* 32.5 *feet; hold,* 5 *feet.*

Immersed section at load-line, 153 *sq. feet. Freight capacity,* 400 *tons* (2000 lbs.).

Cylinders.—Two, 15 ins. in diam. by 5 feet stroke; volume of piston space, [illegible] cube feet.

Wheel.—One, 18 feet in diam.; blades, 2 feet in depth.

Boilers.—Three (cylindrical flued). Diam. 42 ins.; length, 22 feet; 2 flues of [illegible] ins. in each. *Heating surface,* 690 sq. feet. *Grates,* 48 sq. feet.

Pressure of Steam, 160 lbs. per sq. inch, cut off at .375. *Revolutions,* 22 per [illegible]

Consumption of Fuel, 12 tons (2000 lbs.) in 24 hours. *Plating of Hull,* [illegible] .25 inch. *Light draught,* 21 ins.

Iron Propellers.

Vertical Direct Engines (*Non-condensing*).—*Length on deck,* 70 *feet; beam,* [illegible] *feet; draught,* 12 *ins.*

Propellers, 2.—2 blades, 16. ins. in diam., set 11 ins. below water-line.

Boiler (tubular coil). *Revolutions,* 480 per minute.

Speed, 10.49 miles per hour.

Water led to propellers through tunnels in bottom at sides.

"Louise."—Vertical Tandem Engines (*Compound*).—*Length,* 60 *feet; beam,* [illegible] *feet; hold,* 4.25 *feet.*

Displacement at load-draught of 2.5 *feet,* 8 *tons.*

Cylinders, 5 and 10 ins. in diam. by 8 ins. stroke of piston.

Surface Condenser.—*Boiler* (vertical tubular), 4 feet in diam. by 8.5 in length.

Iron Sailing Vessels.

Passenger and Freight.

English.—Ship.—*Length upon deck,* 178 *feet; do. at mean load-line of* 19.[illegible] *feet; keel,* 171 *feet; beam,* 32.88 *feet; depth of hold,* 21.75 *feet; keel* (mean), [illegible]

Immersed section at load-line, 387 *sq. feet. Displacement at load-draught* [illegible] *feet,* 1385 *tons; at* deep load-draught of 20 feet, 1495 *tons; and, in proportion to its* *circumscribing parallelopipedon,* .524.

Load-line.—*Area* at load-draught, 4557 sq. feet. Angle of entrance, 5[illegible] ance, 64°. *Area* in proportion to its circumscribing parallelogram, .7[illegible]

e *of Gravity*, 6.416 feet below mean load-line. *Centre of Displacement* (grav- 6.25 feet below load-line; and 4.33 feet before middle of length of load-line.

rsed *Surface.—Bottom*, 7370 sq. feet. *Keel*, 1130 sq. feet. *Sails*, 13 282 sq. feet.

centre, 6.66 feet above centre of gravity of displacement. *Centre of Effort* entre of displacement, 3.5 feet; height of do. above mean load-line, 55.5 feet.

Launch. Wood.

ɪ LAUNCH "HERRESHOFF."—VERTICAL ENGINE (*Compound*).—*Length*, 33 *feet* *beam*, 8.75 *feet.*

acement at mean load-draught of (to rabbet of keel) 19 *ins.*, 8929 *lbs.*

hts.—Hull and Machinery, 6555 lbs. Coal, 1120 lbs.

Yachts. Wood.

ERICA," SCHOONER.—*Length over all*, 98 *feet; upon deck*, 94 *feet; at load-line*, *t; beam*, 22.5 *feet; at load-line*, 22 *feet; depth of hold*, 9.25 *feet. Height at m under side of garboard strake*, 11 *feet. Sheer, forward*, 3 *feet; aft*, 1.5 *feet*,

rsed section at load-line, 121.8 *sq. feet. Displacement at load-draught of* 8.5 *m under side of garboard strake and of* 11 *feet aft*, 191 *tons; and, in pro- to Volume of circumscribing parallelopipedon*, .375.

acement at 4 *feet* (*from garboard strake*), 43 *tons; at* 5 *feet*, 66 *tons; at* 6 *tons; at* 7 *feet*, 127 *tons; and at* 8 *feet*, 167 *tons.*

e of Gravity.—Longitudinally, 1.75 feet aft of centre of length upon load- ectional, 2.58 feet below load-line. Of Fore body, 14.25 feet forward; and body, 19 feet aft. *Meta-centre*, 6.72 feet above centre of gravity.

e of Effort, 31 17 feet from load-line. *Centre of Lateral Resistance*, 6.33 feet f centre of gravity. *Area of Load-line*, 1280 sq. feet. *Mean girths of im- section to load-line*, 25 feet.

-draught.—Forward, 4.91 feet; aft, 11.5 feet. *Rake of Stem*, 17 feet

s.—Mainmast, 81 feet in length by 22 ins. in diam. *Foremast*, 79.5 feet in y 24 ins. in diam. *Main boom*, 58 feet in length. *Main gaff*, 28 feet. *Fore* feet. *Rake*, 2.7 ins. per foot. *Drag of Keel*, 3 feet. *Tons*, 170.56.

IA," SLOOP.—*Length for tonnage*, 72.25 *feet; on water-line*, 70 *feet* 7 *ins.;* 9 *feet* 8 *ins.; hold*, 6 *feet* 8 *ins. Tons*, O. M. 83.4; N. M. 43.98.

draught, 6.25 *feet.*

—*Mainsail*, hoist, 49.75 feet, foot 54.25, and gaff 27.66; *Jib*, hoist, 49.75 feet, 5, and stay 63.5. *Gaff topsail*, hoist, 24.5 feet.

s.—Mainsail, 2322 sq. feet. Jib, 986, and Topsail, 454.

Cutters.

A" (*English*) SLOOP.—*Length on load-line*, 66 *feet; beam*, 11.5 *feet.*

rsed section at load-line, 11.5 *sq. feet. Displacement*, 75 *tons.*

s.—Mast, deck to hounds, 42 feet. *Boom*, 58 feet. *Gaff*, 39 feet. *Bowsprit* of stem, 30 feet. *Mast to stem*, 26 feet. *Topmast*, foot to hounds, 25 feet. *topsail yard*, 46 feet. *Canvas*, area, 3450 sq. feet. *Tons*, C. H., 90.

st.—At *Keel*, 38.5 tons. *Hull*, 1.5 tons.

CHIEF" (*English*), SLOOP.—*Length on load-line*, 61 *feet; beam*, 19.9 *feet.*

rsed section at load-line, 60 *sq. feet. Displacement*, 55 *tons.*

Pilot Boat.

L H. ASPINWALL," SCHOONER.—*Length of keel*, 74 *feet; upon deck* 9 *feet; hold*, 7.6 *feet. Draught of water*, 6 *feet forward; aft*, 9.5 22 ins. in depth. *False keel*, 12 ins. in depth at centre.

s.—Mainmast, 77 feet in length. *Foremast*, 76 feet. Main bo *ff*, 21 *feet. Fore gaff*, 20 feet.

-*N. M.*, 46.32.

Robinson Street to Kingston Light, 90.375 miles, in 4 *hours*, ma flood tide.

1850, *Buckeye State*, of Pittsburgh, Penn. (non-condensing), Cin burgh, 500 miles (200 passengers), 53 landings, in 1 *day* 19 *hours*, adverse current. Speed = 15.63 *miles* and 1.23 landings per hour. of water in channel 7 feet.

1852, *Reindeer*, of N. Y., New York to Hudson, 116.5 miles, in making 5 landings. Flood tide.

1853, *Shotwell*, of Louisville, Ky. (non-condensing), New Orlea 1450 miles, 8 landings, in 4 *days* 9 *hours*; 4.5 to 5.5 miles per h rent. Speed = 18.81 *miles* per hour.

Note.—In 1817–18 the average duration of a passage from New Orleans to Lo 12 *hours*; the shortest, 25 *days*.

1855, *New Princess*, of New Orleans (non-condensing). New Orleans Miss., 310 miles, in 17 *hours* 30 *min.*; 3.5 to 4 miles per hour Speed = 20.98 *miles* per hour.

1864, *Daniel Drew*, of N. Y., Jay Street, N. Y., to Albany, 148 mi *min.*, 9 landings. Flood tide. Speed of boat = 22.6 *miles* per hou

1867, *Mary Powell*, of N. Y., Desbrosses Street, N. Y., to Newbur 2 *hours* 50 *min.*, 3 landings; from Poughkeepsie to Rondout Light, 39 *min.*, flood tide. 1873, Milton to Poughkeepsie, light draught miles, in 9 *min.*; and 1874, Desbrosses Street to Piermont, 24 mil Caldwell's, 43.25 miles, in 1 *hour* 50 *min.* Speed = 22.77 to 23 *mil*

Runs from New York to Albany, 146 *miles, by differen*

1826, *Sun*.............	12 *hours*	16 *min.*	1852, *Fr. Skiddy* §......	
1826, *North America* *.	10 "	20 "	1860, *Armenia* ‖........	
1841, *Troy* †..........	8 "	10 "	1864, *Daniel Drew* ‡....	
1841, *South America* ‡.	7 "	28 "	1864, *Ch'ncey Vibbard* ‡.	

* 7 landings. † 4 landings. ‡ 9 landings. § 6 landings.

***Timing Distance.*—From 14th St., Hudson River, N. Y., to College at Mount St.**

Note.—Where landings have been made, and the river crossed, the distance given is correspondingly increased.

1870, *R. E. Lee*, of St. Louis (non-condensing), New Orleans to St. miles (without passengers or freight), 4 to 5 miles per hour adverse

PASSAGES OF STEAMERS AND SAILING VESSELS.

Distances in Geographical Miles or Knots.

Steamers. Side-wheels.

807, *Phœnix*, of Hoboken, N. J. (John Stevens), New York, N.Y., to Philadelphia, in. First passage of a steam vessel at sea.

814, *Morning Star*, of Eng., River Clyde to London, Eng. First passage of an glish steamer at sea.

817, *Caledonia*, of Eng., Margate, Eng., to Cassel, Germ., 180 miles, in 24 *hours*.

1819, *Savannah*, of N.Y., about 340 tons O. M., Tybee Light, Savannah River, Ga., Rock Light, Liverpool, Eng., 3640 miles, in 25 *days* 14 *hours;* 6 *days* 21 *hours* of ich were under steam.

825, *Enterprise*, of Eng., 500 tons, Falmouth, Eng., to Table Bay, Africa, in 57 *ys;* and to Calcutta, India, in 113 days. First passage of a steamer to India.

830, *Hugh Lindsay*, 411 tons, 80 HP, Bombay, India, to Suez, Egypt, 3103 miles, 31 *days* running time.

837, *Atlanta*, of Eng., 650 tons, Falmouth, Eng., to Calcutta, in 91 days.

839, *Great Western*, of Eng., Liverpool to New York, N. Y., 3017 miles, in 12 *s* 18 *hours*.

870, *Scotia*, of Eng., Queenstown, Ireland, to Sandy Hook, N. J., 2780 miles, in *ays* 7 *hours* 31 *min.* 1866, New York to Queenstown, 2798 miles, in 8 *days* 2 *rs* 48 *min.;* thence to Liverpool, Eng., 270 miles, in 14 *hours* 59 *min.;* total, 8 *s* 17 *hours* 47 *min.*

Screw.

874, *India Government Boat*, Steel, length 87 feet, beam 12 feet, draught of water 5 feet, mean speed for one mile 20.77 miles per hour, and maintained a speed of 92 miles in 1 *hour*.

877, *Lusitania*, of Eng., London to Melbourne, Australia, via Cape, 11 445 miles, 38 *days* 23 *hours* 40 *min.*

Sailing Vessels.

1851, *Chrysolite* (clipper ship), of Eng., Liverpool, Eng., to Anjer, Java, 13 000 les, in 88 *days*. The *Oriental*, of N. Y., ran the same course in 89 *days*.

1853, *Trade Wind* (clipper ship), of N. Y., San Francisco, Cal., to New York, N. Y., 510 miles, in 75 *days*.

854, *Lightning* (clipper ship), of Boston, Mass., Melbourne, Australia, to Liver- l, Eng., 12 190 miles, in 64 *days*.

854, *Comet* (clipper ship), of N. Y., Liverpool, Eng, to Hong Kong, China, 13 040 es, in 84 *days*.

854, *Sierra Nevada* (schooner), of N. H., Hong Kong, China, to San Francisco, ., 6000 miles, in 34 *days*.

854, *Red Jacket* (clipper ship), of N. Y., Sandy Hook, N. J., to Melbourne, Aus- ia, 12 720 miles, in 69 *days* 11 *hours* 1 *min.*

855, *Euterpe* (half-clipper ship) of Rockland, Me., New York to Calcutta, India, 500 miles, in 78 *days*.

860, *Andrew Jackson* (clipper ship), of Boston, New York, N. Y., to San Fran- co, Cal., 13 610 miles, in 80 *days* 4 *hours*.

865, *Dreadnought* (clipper ship), of Boston, Honolulu, Sandwich Islands, to New dford, Mass., 13 470 miles, in 82 *days;* and 1859, Sandy Hook, N. J., to Rock ht, Liverpool, Eng., 3000 miles, in 13 *days* 8 *hours*.

865, *Sovereign of the Seas* (medium ship), of Boston, Mass., in 22 days sailed 1 miles = 245 miles per day. For 4 *days* sailed 341.78 miles per day, and for 1 *y* 375 miles.

1866, *Henrietta* (schooner yacht), of N. Y., Sandy Hook, N. J., to g., 3053 miles, in 13 *days* 21 *hours* 55 *min.* 16 *sec.*

1866, *Ariel* and *Serica* (clipper ships), of England, Foo-chou-foo Downs, Eng., 13 500 miles, in 98 *days*.

869, *Sappho* (schooner yacht), of N. Y., Light-ship off Sandy enstown, Ireland, 2857 miles, in 12 *days* 9 *hours* 34 *min.*

2.17 lbs. per sq. inch. *Revolutions*, 22 per minute.

Pipes, 3 feet in diam. = 168 area of cylinder.

Tuyeres.—Each Furnace, 2 of 3 ins. in diam.; 1 of 3.25 ins.; and Each Finery, 6 of 1.33 ins.; and 1, 4 of 1.125 ins.

Temperature of Blast, 600°. *Ore*, 40 to 45 per cent. of iron.

Furnaces.—Eight, diam. 16 *to* 18 *feet. Dowlais Iron Works*

1300 *Tons Forge Iron per Week; discharging* 44 000 *Cube Fe*
Minute.

Engine (non-condensing).—*Cylinder*, 55 ins. in diam. by 13 feet st

Pressure of Steam.—60 lbs. per sq. inch, cut off at .33 the stroke of p 120 ins. in area.

Boilers.—Eight (cylindrical flued, internal furnace), 7 feet in diam. length; one flue 4 feet in diam. *Grates*, 288 sq. feet.

Fly Wheel.—Diam., 22 feet; weight, 25 tons.

Blowing Cylinder, 144 ins. in diam. by 12 feet stroke of piston.

Revolutions, 20 per minute. *Blast*, 3.25 lbs. per sq. inch. *Dischar* 5 feet, and 420 feet in length. *Valves.*—Exhaust, 56 sq. feet; Deliver

Furnaces.— *Lackenby* (*England*).

800 *Tons Iron per Week.*

Engine (horizontal, compound condensing).—32 and 60 ins. in feet stroke of piston.

Blowing Cylinders.—Two, 80 ins. in diam. by 4.5 feet stroke of pist 4.5 lbs. per sq. inch. *Revolutions*, 24 per minute.

Pipe, 30 ins. in diam.; *volume*, 12.25 times that of blowing cylinder

IP.—Engine, 290 lbs.; Blowing cylinders, 258; efficiency, 89 per ce

Valves.—Area of admission, .16 of area of piston; of exit, .125.

Volume.—190 000 cube feet of air are supplied per ton of air.

Blower and Exhausting Fan.

COTTON FACTORIES. (*English.*)

'riving 22 060 Hand-mule Spindles, with Preparation, and 260 Looms, with common Sizing.

ıgine (condensing).—*Cylinder*, 37 ins. in diam. by 7 feet stroke of piston; e of piston space, 53.6 cube feet.

ssure of Steam.—(Indicated average) 16.73 lbs. per sq. inch. *Revolutions*, 17 inute.

tion of Engine and Shafting.—(Indicated) 4.75 lbs. per sq. inch of piston.

125. Total power = 1. Available, deducting friction = .717.

ES.—Each IHP will drive { 305 hand-mule spindles, *with preparation*,
or 230 self-acting " "
or 104 throstle " "
or 10.5 looms, with common sizing.

uding preparation :
1 throstle spindle = 3 hand-mule, or 2.25 self-acting spindles.
1 self-acting spindle = 1.2 hand-mule spindles.

DREDGING MACHINES.

ing 20 Feet from Water-line, or 180 Tons of Mud or Silt per Hour 11 Feet from Water-line.

gth upon deck, 123 *feet; beam*, 26 *feet. Breadth over all*, 41 *feet.*

ersed section at load-line, 60 *sq. feet. Displacement*, 141 *tons, at load-draught* *feet.*

ıgine (non-condensing).—*Cylinders*, two, 12.125 ins. in diam. by 4 feet stroke on.

ers.—Two (cylindrical flue), diam. 40.5 ins., and length, 20 feet 3 ins.; two 14.625 ins. in diam. *Heating surface*, 617 sq. feet. *Grates*, 37 sq. feet.

ssure of Steam, 25 lbs. per sq. inch; throttle .25 open, cut off at .5 the stroke on. *Revolutions*, 42 per minute.

kets.—Two sets of 12, 2.5 feet in length by 15 ins. at top and 2 feet deep; vol- 5.25 cube feet. *Chain Links*, 8 ins. in length by .5 inch diam.

ws or Camels.—Four, of 40 tons capacity each.

STEAM HOPPER DREDGER. (*Wm. Simons & Co.*)

Iron.

EPTUNE" (*English*).—*Length*, 150 *feet; breadth*, 32 *feet.*

redge from 6 Ins. to 25 Feet. Capacity of Hopper, 500 *to* 600 *Tons.*

ıgines.—Two (compound), 375 IHP, for dredging and propulsion, and one for g bucket-frame and anchor-posts.

ke designed dredger of 1000 tons' capacity has dredged 25 000 tons silt per and transported it 4 miles.

Dredging 1000 Tons of Mud or Silt per Hour, 5 to 35 Feet in Depth. Capacity of Hopper, 1000 Tons.

rines.—Two (compound), IHP 1000. *Speed.*—9 knots per hour.

Steam Dredging Crane. (*English.*)

Lift, 30 Feet per Hour.

Lifting Power.	Volume of Bucket.	Mud or Silt.	Coal and Sand.	Excavation Ground.	Weight of Crane.	Lifting Power.	Volume of Bucket.	Mud or Silt.	Coal and Sand.
Tons.	*Lbs.*	Tons.	Tons.	C. Yds.	Lbs.	Tons.	Lbs.	Tons.	Tons.
2.5	*1120*	*25*	20	20	18 000	5	2240	50	40
3	*1680*	*37.5*	32	25	33 480	7	3360	60	54

Electric Launch. Steel.

"HILDA," "MARY," "FLO," and "THEO."—*Length*, 40 *feet*; *Beam*, 6.5; [illegible] 3.1.—*Load-draught*, 40 *passengers*, 1.66 *feet*. *Motor*, HP 3.5. *Revolutions*, 700 [illegible] minute. *Speed*, 6 miles per hour.

Accumulators, under the seats, and when fully charged, capacity for 8 hours [illegible] full speed. *Charging* is effected at landings at termination of route.

Builders.—J. B. Seath & Co., Glasgow, Scotland.

HOPPER DREDGER "BELFAST NO. 3." IRON AND STEEL.—*Length over all*, 190 [illegible] *on deck*, 189; *between perpendiculars and for tonnage*, 185; *Beam*, 38.5 *feet*; [illegible] 14.1 *feet*; *Tonnage, Gross*, 760 *tons*; *Net*, 372; *Mean draught*, 9.5 *feet*, *loaded*, [illegible]

Displacement, 1860 *tons*. *Immersed Section*, 490 □ *feet*. *Freeboard*, 2.75 *feet*.

Dredging Capacity, 1000 tons per hour.

Cylinders. Two of 20 ins. in diam. and two of 38.5 ins. Stroke of piston 30 ins.

Pressure of Steam, 90 lbs. per □ inch. *Revolutions* per minute, 80. HP 850.

Boilers, two. *Grate surface*, 81 □ feet. *Heating surface* 2120, and *Condensing* [illegible] *Propeller*, 9 feet in diameter. *Fuel*, capacity 50 tons. *Crew*, 13.

Weight, Hull, 500 tons. *Speed*, 8.5 knots per hour.

Builders.—Wm. Simons & Co., Renfrew, Scotland.

"HERCULES," *Panama Canal.*—*Length on deck*, 100 *feet*; *beams*, 40, 60, and [illegible] *feet*; *depth of hold*, 12 *feet*. *Slot*, 36 *feet in length by* 6 *feet* 7 *ins. in width*.

Ways.—Two, one 40 feet and one 60 feet, by 5 feet in width.

Buckets.—38; volume, 1.33 cube yards. *Spuds*, 2 feet in diam. and 60 in length.

Engines.—Two of 100 HP each, and two of 40 HP each.

Boilers.—Three (horizontal tubular), 16 feet in length.

Elevator and Discharge.—Maximum, 24 cube yards per minute.

Crane. (Wood.)

Hull.—*Length on deck*, 100 *feet*; *beam*, 44 *feet*; *load-draught*, 4.5 *feet*.

Radius of crane, 46 feet; *height*, 70 feet; *counter-balance*, 70 tons.

Boiler.—*Heating surface*, 500 sq. feet. *Pressure of Steam*, 80 lbs. per sq. inch. HP, 150.

Propellers.—Two, 4.25 feet in diam. *Speed*, 5 miles per hour.

Engine to operate crane. *Cylinder.*—10 ins. in diam. by 12 ins. stroke of piston.

FLOUR MILLS.

30 *Barrels of Flour per Hour.*

Water-wheels, *Overshot.*—5, diam. 18 feet by 14.5 feet face. *Buckets*, 15 ins. in depth. *Water.*—*Head*, 2.5 feet. *Opening*, 2.5 ins. by 14 feet in length over each wheel.

5 *Barrels of Flour per Hour, and Elevating* 400 *Bushels of Grain* 36 *Feet.*

Water-wheel, *Overshot.*—Diam. 22 feet by 8 feet face. *Buckets*, 52 of 1 foot in depth. *Water.*—*Head*, from centre of opening, 25 ins. *Opening*, 1.75 ins. by 80 ins. in length.

Revolutions, 3.5 per minute. *Stones*, three of 4.5 feet; revolutions, 130.

Three Run of Stones, Diameter 4 *Feet.*

Water-wheel, *Overshot.*—Diam. 19 feet by 8 feet face. *Buckets*, 14 ins. in

Or,

[illegible]ine (non-condensing).—Cylinder, 13 ins. in diam. by 4 feet stroke.

[illegible] flued).—Diam. 5 feet by 30 in length; two flues 20 ins. in diam.

HOISTING ENGINES.

For Pile Driving, Hoisting, Mining, etc.

Lidgerwood Manuf'g Co., New York.

	SINGLE CYLINDERS.			DOUBLE CYLINDERS.			
•	Cylinder.	Capacity.	Cost, with Boiler.*	HP	Cylinder.	Capacity.	Cost, with Boiler.*
•.	Ins.	Lbs.	$	No.	Ins.	Lbs.	$
ŀ	5 × 5	1000	600	8	5 × 8	2000	950
5	6 × 8	1250	675	12	6 × 8	2500	1050
ɔ	7 × 10	1800	825	20	7 × 10	3500	1350
5	8 × 10	2800	1050	30	8 × 10	6000	1550
ɔ	9 × 12	4000	1275	40	9 × 12	8000	2000
5	10 × 12	5000	1375	50	10 × 12	9000	2350

* Complete.

Details and Operation.

:ne.	Drum.	Boiler. Dimensions.	Boiler. Tubes.	Ram.	Leaders. Hoist.	Lift. Ram.	Blows per Minute.	Piles per 10 Hours.	Fuel per Hour.
?	Ins.	Ins.	No.	Lbs.	Feet.	Feet.	No.	No.	Lbs.
ɔ*	12 × 24	32 × 75	48 of 2 in.	1953	40	8 to 12	25	50	70
ɔ	14 × 26	40 × 84	80 of 2 in.	2700	75	8 to 12	29	100	80

* Weight complete, 8500 lbs.

Mining Engines and Boilers. (*Various Capacities.*)

'ngine, Boiler, etc., as given for Pile Driving, page 902.

'peration. — 250 to 300 tons of coal in 10 hours. *Fuel*, 40 lbs. coal per hour. *ter*, 20 gallons per hour.

Veight of Engine and Boiler, 4500 lbs.

Hancock Inspirator. *For a Lift of Water of 25 Feet.*

o.	Diameter. Steam-pipe.	Diameter. Suction.	Discharge at Pressure of 60 Lbs.	No.	Diameter. Steam-pipe.	Diameter. Suction.	Discharge at Pressure of 60 Lbs.
	Ins.	Ins.	G'lls. per h'r.		Ins.	Ins.	G'lls. per h'r.
'	.375	.5	120	30	1.25	1.5	1260
:.5	.5	.75	220	35	1.25	1.5	1740
;	.5	.75	300	40	1.5	2	2230
'	.75	1	540	45	1.5	2	2820
;	1	1.25	900	50	2	2.5	3480

emperature of water not over 145° for a low lift, and 100° for a high lift.

HYDROSTATIC PRESS. (*Cotton.*)

30 *Bales of Cotton per Hour.*

Engine (non-condensing).—*Cylinder*, 10 ins. in diam. by 3 feet stroke of piston.

'ressure of Steam, 50 lbs. per sq. inch, full stroke. *Revolutions*, 45 to 60 per ıute.

'resses.—Two, with 12-inch rams; stroke, 4.5 feet.

'umps.—Two, diam. 2 ins.; stroke, 6 ins.

For 83 *Bales per Hour.*

Engine (non-condensing).—*Cylinder*, 14 ins. in diam. by 4 fee'

3oilers.—Three (plain cylindrical), 30 ins. in diam. and 26 feet i sq. feet. *Pressure of Steam*, 40 lbs. per sq. inch. *Revolutions*

'resses.—Four, geared 6 to 1, with two screws, each of 7.5 ins pitch.

'haft (wrought iron).—Journal, 8.5 ins. Fly Wheel, 16 fee' *lbs.*

Cost.—Average per mile in England, 2.52 pence sterling = 4.48 cent

PILE-DRIVING.

Driving One Pile.

Engine (non-condensing).—*Cylinder*, 6 ins. in diam. by 1 foot str

Boiler (vertical tubular).—32 ins. in diam., and 6.166 feet in height. sq. feet. *Furnace*, 20 ins. in height. *Tubes*, 35, 2 ins. in diam., 4.5 fe

Revolutions, 150 per minute. *Drum*, 12 ins. in diam., geared 4 to 1. feet in height. *Ram.*—2000 lbs., 2 blows per minute. *Fuel*, 30 lbs. co

Driving Two Piles.

Engine (non-condensing).—*Cylinders*, two, 6 ins. in diam. by 18 i piston.

Boiler (horizontal tubular).—*Shell*, diam. 3 feet, and 6 feet in leng end 3.75 feet in width, 3.5 feet in length, and 6 feet in height.

Pressure of Steam, 60 lbs. per sq. inch. *Revolutions*, 60 to 80 per mi

Frame, 8.5 feet in width by 26 feet in length. *Leaders*, 3 feet in wid in height. *Rams.*—Two, 1000 lbs. each, 5 blows per minute.

PUMPING ENGINES.

CORLISS STEAM-ENGINE Co., *Providence, R. I.*—VERTICAL-BEAM E *pound).*—*Cylinders.*—18 and 36 ins. in diam. by 6 feet stroke of piston

Pumps.—Four plunger, 19 ins. in diam. by 3 feet stroke of piston. per revolution of engine, 84.96 cube feet.

Boilers.—Three, vertical fire tubular. *Grate.*—93 sq. feet. *Heating* sq. feet. *Pressure of Steam*, 125 lbs. per sq. inch, cut off at .22 feet. 36 per minute. IHP 313. *Fly-wheel.*—25 feet in diam., weight 62 000 l

Fuel.—Cumberland coal, 486 lbs. per hour, inclusive of kindling and r *Ash and Clinkers*, 9.4 per cent. *Duty* for one week, 113 271 000 *foot-lb*

Water delivered, 17 621 gallons per minute, against head of 180 feet.

Duty, average for 1883, per 100 lbs. anthracite coal, 106 048 000 *foot-lb*

For Elevating 200 000 Gallons of Water per Hour.

"*Gaskill*," *at Saratoga, N. Y.*

ıgine (*Horizontal Compound*). *Cylinders*.—High pressure, 2 of 21 ins. diam. ›ressure, 2 of 42 ins. diam., all 3 feet stroke of piston. *Pumps*.—Two of 20 ins. by 3 feet stroke of piston.

' *Wheel*, 12.33 feet in diam.; weight, 12 000 lbs.

lers (horizontal tubular).—Two of 5.5 feet in diam. by 18 feet in length. *Heat- urface*, 2957 sq. feet. *Grates*, 51 sq. feet of grate; to heating surface, 1 to 58, o transverse section of tubes, 1 to 7. *Chimneys*, 75 feet.

ıssure of Steam.—Mean of 20 hours, 74.25 lbs. per sq. inch. *Revolutions*, 17.87 ıinute. IHP.—High-pressure cylinders, 109.2; low-pressure, 76 65. Total, 185.8.

el.—Anthracite, 6.9 lbs. per sq. foot of grate per hour. *Evaporation*, per sq. ›f heating surface per hour, 1.175 lbs.; per lb. of coal, 9.25 lbs.; per cent. of ›ombustible, 3.2.

ty, 112 899 993 foot-lbs. per 100 lbs. coal. *Heating surface* per IHP, 14.9.

am per sq. foot of surface per hour, 1.19 lbs.; per sq. foot of surface per lb. of ›er hour from 212°, 11.28 lbs.

Ericsson's Caloric. *For an Elevation of* 50 *Feet.*

	Space occupied.		Volume per Hour.	Pipes, Suction and Dis-charge.	Fuel per Hour.		COST. Furnace.		Deep Well Pump. Extra.		
	Floor.	Height.			Nut Anthr.	Gas.	Gas.	Coal.	Pump.	Pipes per Foot. Plain.	Galvan.
	Ins.	Ins.	Gall.	Ins.	Lbs.	Cub. ft.	$	$	$	$	$
	34×18	48	150	.75	—	15	150	—	—	—	—
	39×20	51	200	.75	2.5	18	200	210	—	—	—
	48×21	63	350	1	3.3	25	235	250	10	.64	.86
	54×27	63	800	1.5	6	—	—	320	15	.80	1.15
*	42×52	65	1600	2	12	—	—	450	25†	.92	1.25

* Over 90 feet, 92 cents. † Duplex.

›luding engine and pump, oil-can and wrench, complete in all but suction and ıarge-pipe.

SUGAR MILLS.

ressing 40 000 *lbs. Cane-juice per day, or for a Crop of* 5000 *Boxes of* 450 *lbs. each in four Months' Grinding.*

ngine (non-condensing).—*Cylinder*, 18 ins. in diam. by 4 feet stroke of piston.

iler (cylindrical flued).—64 ins. in diam. and 36 feet in length; two return flues, s. in diam. *Heating surface*, 660 sq. feet. *Grates*, 30 sq. feet.

essure of Steam, 60 lbs. per sq. inch, cut off at .5 the stroke of piston. *Revolu* ı 40 per minute.

lls.—One set of 3, 28 ins. in diam. by 6 feet in length; geared 1 to 14. *Shafts*, ıd 12 ins. in diam. *Spur Wheel*, 20 feet in diam. by 1 foot in width. *Fly l*, 18 feet in diam.; weight, 17 400 lbs.

ights.—Engine, 61 460 lbs.; Sugar Mill, 65 730 lbs.; Spur Wheel and Connect- ſachinery to Mill, 28 680 lbs.; Boiler, 18 520 lbs.; Appendages, 6730 lbs. Total, 20 lbs.

STONE AND ORE BREAKERS. (*See p.* 957.)

Re-ceiver.	Pulley. D'm.	Face.	V'locity per Minute.	Power re-quired.	Weight.	No.	Re-ceiver.	Pulley. D'm.	Face.	V'locity per Minute.	Power re-quired.	Weight.
Ins.	Feet.	Ins.	Feet.	HP.	Lbs.		Ins.	Feet.	Ins.	Feet.	HP.	Lbs.
4×10	1.66	6	250	4	4 000	5	9×15	2.5	9	250	9	13 360
5×10	2.75	6	180	5	6 700	6	11×15	2.33	6	180	9	11 600
7×10	2	7.5	250	6	8 000	7	13×15	2 33	8	180		
5×15	2.33	8	180	9	9 100	8	15×20	3 5	10	150		
7×15	2.33	9	180	9	10 490	9	18×24	6	12	125		

OTE.—Amount of product depends on distance jaws are set apart, luct given in Table is due when jaws are set 1.5 ins. open at bott *e is run at its proper speed* and *diligently fed*. It will also vary sc *acter of stone*. Hard stone or ore will crush faster than sandstoı *ube yard of stone is* about one and one third tons.

STEAM FIRE-ENGINE.

Amoskeag, N. H. 1st Class.

Steam Cylinder.—Two of 7.625 ins. in diam. by 8 ins. stroke of piston.

Water Cylinder.—Two of 4.5 ins. in diam.

Boiler (vertical tubular).—*Heating surface,* 175 sq. feet. *Grates,* 4.75 sq. fe

Pressure of Steam.—100 lbs. per sq. inch. *Revolutions,* 200 per minute.

Discharges.—Two gates of 2.5 ins., through hose, one of 1.25 ins. and two of

Projection.—Horizontal, 1.25 ins. stream, 311 feet; two 1 inch streams, Vertical, 1.25 ins. stream, 200 feet. *Water Pressure.*—With 1.125 ins. nozzle,

Time of Raising Steam.—From cold water, 25 lbs., 4 min. 45 sec.

Weights.—Engine complete, 6000 lbs.; water, 300 lbs.

SAW-MILL.

Two Vertical Saws, 34 Ins. Stroke, Lathes, etc.

Engine (non-condensing). *Cylinder.*—10 ins. in diam. by 4 feet stroke of

Boilers.—Three (plain cylindrical), 30 ins. in diam. by 20 feet in length.

Pressure of Steam.—90 lbs. per sq. inch. *Revolutions,* 35 per minute.

NOTE.—This engine has cut, of yellow-pine timber, 30 feet by 18 ins. in 1 m

STONE SAWING.

Emerson Stone Saw Co. (Diamond Stone Saw, Pittsburgh, Pen 20 IP, 150 sq. feet of Berea sandstone, inclusive of both sides of cut, in 1 hour

CHIMNEYS.

LAWRENCE, *Mass. Octagonal,* 222 *Feet above Ground, and* 19 *Feet Foundation,* 35 *Feet square and of Concrete* 7 *Feet deep.* (*Hiram F. Mill*

Shaft.—234 feet in height, 20 feet at base, and 11.5 at top; 28 ins. thick and 8 at top. *Core.*—2 feet thick for 27 feet, and 1 foot for 154.

Horizontal Flues.—7.5 feet square, and *Vertical* flue or cylinder of 8.5 fe high, with walls 20 ins. thick for 20 feet, 16 for 17 feet, 12 for 52 feet, and 8 for

Purpose.—For 700 sq. feet grate surface. *Weight.*—2250 tons. *Bricks,*

NEW YORK STEAM HEATING CO. *Quadrilateral,* 220 *Feet above Gr and* 1 *Foot below.* (*Chas. E. Emery, Ph. D.*)

Shaft.—220 feet in height, and 27 feet 10 ins. by 8 feet 4 ins. in the clear

Foundation.—1 foot below high water. *Capacity.*—Boilers of 16 000 IP.

Cost of Steam-Engines and Boilers complete, and Operation per Day of 10 Hours, inclusive of La Fuel, and Repairs. (*Chas. E. Emery, Ph. D.*)

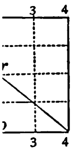
IP.	Engine.		Water Evaporated per IP per Hour.	Water Evaporated per Lb. of Coal.	Coal per IP.	Coal per Day.	Labor.	Supplies and Repairs.	Cost of Coal.*
			Lbs.	Lbs.	Lbs.	Lbs.	$	$	$
6.25	Portable Vertical	Non-cond'g.	42	7.5	56	394	1.75	.33	.73
12.5	" "	Non-cond'g.	38	7.5	51	717	1.75	.41	[illegible]
29	Horizontal......	Non-cond'g.	32	8	40	1 308	2.25	.60	[illegible]
112	Single Condensing...		23	8.8	26.1	3 300	3.75	1.17	[illegible]
276	" " ...		22.2	8.8	25.2	7 831	4.25	2.12	[illegible]
552	" " ...		22.2	8.8	25.2	15 663	6	[illegible]	[illegible]

* $4.42 per ton (2240 lbs.), including cartage.

GRAPHIC OPERATION.

ns of Questions by a Graphic Operation.

ıan walks 5 miles in 1 hour, how far will he walk in 4 hours?



Operation.—Draw horizontal line, divide it into equal parts, as 1, 2, 3, and 4, representing hours. From each of these points let fall vertical lines A C, 1 1, etc., and divide A C into miles, as 5, 10, 15, and 20, and from these points draw equidistant lines parallel to the horizontal.

Hence, the horizontal lines represent time or hours, and the vertical, distance or miles.

Therefore, as any inclined line in diagram represents both time and distance, course of man walking 5 miles in an hour is represented by diagonal A *e*; and if he walks for 4 hours, e time to 4, and read off from vertical line A C the distance = 20 *miles*.

far will a man walk in 2 hours at rate of 10 miles in 1 hour?

e is shown by the line A *o*, representing 20 *miles*.

o men start from a point at the same time, one walking at the iiles in an hour and the other at 10 miles, how far apart will they nd of 2 hours?

rses being shown by the lines A *r* and A *o*, the distance *r o* represents ce of their distances, 10 ∾ 20 = 10 *miles*.

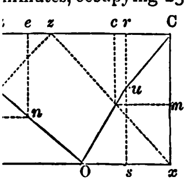
long have they been walking?

rses are now shown by the lines A *o* and A 4, the distance 2 4 represents ce of their times, or 2 ∾ 4 = 2 *hours*.

ı they are 10 miles apart, how long have they been walking?

rses are again shown by the lines A *r* and A *o*, the distance *r o* repre- fference of their distances of 10 miles, and A 2, 2 *hours*.

ıan walks a given distance at rate of 3.5 miles per hour, and then of distance back at rate of 7 miles, and walks remainder of dis- minutes, occupying 25 minutes of time in all, how far did he run?



Operation.—Draw horizontal line, as A C, representing whole time of 25 minutes; set off point *e* representing a convenient fraction of an hour (as 10 minutes), and *a i* equal to corresponding fraction of 3.5 miles (or .5833); draw diagonal A *n*, produced indefinitely to O, and it will represent the rate of 3.5 miles per hour.

Set off C *r* equal to 5 minutes, upon same scale as that of A C; let fall vertical *r s*, and draw diagonal C *u* at same angle of inclination ι *n*; then from point *u* draw diagonal *u* O, inclined at such a rate as to miles per hour; thus, if *i n* represents rate of 3.5 miles, *s* O, being one distance, will represent 7 miles.

e distance between the two points is thus determined by C *x*, and dis- y *u s*, measured by scale of miles employed.

ion.—The distances A *e* and A *i* are respectively 10 minutes = .166 of an 5833 mile = .166 of 3.5 miles. Hence, C *x* = .875 mile, and *u s* = .5833 sequently, the man walked A O = .875 mile = 15 minutes, ran O *u* = = 5 minutes, and walked *u* C = .2916 *mile*.

second man were to set out from C at same time the man referred ding question started from A, and to walk to A and m rate of speed and occupying same time of 25 min times will he meet the first man?

ı.—As A C represents whole time, and C *x* distance be ınd *z x* will represent course of second man walking at *meet the first man*, on his outward course, at a distance *A, represented* by A *o*, and at the time A *a*; and on t... ı *v*, *x m*, and at the time A *c*.

MISCELLANEOUS.

No., Diameter, and Number of Shot. (*American Standard*)

Compressed Buck Shot.

No.	Diam.	Shot per Lb.	No.	Diam.	Shot per Lb.	No.	Diam.	Shot per Lb.
	Inch.	No.		Inch.	No.		Inch.	No.
3	.25	284	1	.3	173	00	.34	115
2	.27	232	0	.32	140	000	.36	98

Balls, .38 Inch, 85 No. per lb.; .44 Inch, 50 No. per lb.

Chilled Shot.

No.	Diam.	Shot per Oz.	No.	Diam.	Shot per Oz.	No.	Diam.	Shot per Oz.	No.	Diam.	Shot per Oz.
	Inch.	No.		Inch.	No.		Inch.	No.		Inch.	No.
12	.05	2385	9	.08	585	6	.11	223	1	.16	73
11	.06	1380	8	Trap	495	5	.12	172	B	.17	[illegible]
10	Trap	1130	8	.09	409	4	.13	136	BB	.18	[illegible]
10	.07	868	7	Trap	345	3	.14	109	BBB	.19	[illegible]
9	Trap	716	7	.1	299	2	.15	88			

Drop Shot.

No.	Diam.	Pellets per Oz.	No.	Diam.	Pellets per Oz.	No.	Diam.	Pellets per Oz.	No.	Diam.	Pellets per Oz.
	Inch.	No.		Inch.	No.		Inch.	No.		Inch.	No.
Extra Fine Dust	.015	84 021	9	Trap	688	5	.12	168	BBB	.19	[illegible]
Fine Dust	.03	10 784	9	.08	568	4	.13	132	T	.2	[illegible]
Dust	.04	4 565	8	Trap	472	3	.14	106			
12	.05	2 326	8	.09	399	2	.15	86	TT	.21	31
11	.06	1 346	7	Trap	338	1	.16	71	F	.22	27
10	Trap	1 056	7	.1	291	B	.17	59			
10	.07	848	6	.11	218	BB	.18	50	FF	.23	24

The scale of the Le Roy standard (adopted by the Sportsman's Convention) commences with .21 inch for TT shot, and reduces .01 inch for each size to .05 inch for No. 12. The number of pellets per oz. being the actual number in perfect shot.

The number of pellets by this standard is nearly identical with that of the American Standard.

Tatham's scale is same as Le Roy's, but number of pellets is deduced mathematically, by computing them from the specific gravity of the lead.

Drains, Diameter and Grade of, to Discharge Rainfall.

Diam.	Grade 1 Inch.	Acres.	Diam.	Grade 1 Inch.	Acres.	Diam.	Grade 1 Inch.	Acres.	Diam.	Grade 1 Inch.	Acres.
Ins.			Ins.			Ins.			Ins.		
4	30	.5		40	1.2		60	2.1		80	5.8
	20	.6		20	1.5	9	120	2.1	15	240	7.8
5	80	.5	7	20	1.2		80	2.5		120	7.8
	60	.6		60	1.5		60	2.75		80	9
	[illegible]	1	8	120	1.5	12	120	4.5		60	10
6	60	1		80	1.8		80	5.3	18	240	10

British and Metric Measures, Commercial Equivalents of. (G. Johnstone Stones, *F. R. S.*)

	Millimeters.	Weight.	Grammes.	Volume.	Cubic Centimeters.
......	914.4	Pound..........	453.6	Gallon..........	4554
....	304.8	Ounce..........	28.35	Quart..........	1139
...	25.4	Grain..........	.0648	Ounce..........	

MEMORANDA.

ınd Mechanical Elements, Constructions, and Results.

Double. — 600 IP (to be transmitted) ÷ velocity of belt in feet per P ÷ number of revolutions per minute × diameter of pulley in feet *Machine Belts.* — 1500 to 2000 IP ÷ velocity of belt in feet per in ins. (*Edward Sawyer.*)

›e of a Locomotive. Best height is from 6 to 8 diameters effect when expanded to full diam. of pipe at 2 diameters from base.

ıveting. A riveting gang (2 riveters and 1 boy) will drive in shell, mean of 12.5 rivets per hour.

Compressed Fuel is composed of coal dust agglomerated r, compressed in molds, and subjected to a high temperature in an o expel the moisture or volatile portion of the pitch and any fire-exist in the cells of the coal.

ighest. At Garabil, France, 413 feet from floor to surface of water, length.

Malleable. P. Dronier, in Paris, makes alloys of copper and adding from .5 per cent. to 2 per cent. quicksilver.

ʒ Department, Requirements of. (*New York.*)

s of Dwelling Houses hereafter constructed at least 8-inch walls on inner 4 ins. of which, from bottom of flue to a point two feet above ıilt of fire-brick laid with fire-clay mortar; and least dimensions of ıs. square, or 4 ins. wide and 16 ins. long, inside measure; and when ɔ located in the usual stacks, side of flue inside of house to which it 4 ins. thick. If preferred, furnace flues may be made of fire-clay size, built in the walls, with an air space of 1 inch between them, ːk wall on outside.

.o be lined with fire-brick at least 25 feet in height from bottom, ᵃalls of said flues to be less than 8 ins. thick.

uilt for furnaces or boilers must be altered to conform to the above ·fore they are used as such.

ɜ, Protection of, from Lightning. A wire rope of ɜ held to be the most efficient.

:tors, weighing 8 lbs. per yard and 4 lbs. for duplicated and all others, 50 feet apart, thus bringing every portion of the building to which ı within 25 feet of their protection.

st material for a conductor; it should be continuous, and all joints ral points are preferable to one, and greater surface should be given vith the earth than usually practised. (*Sir W. Thompson.*)

ırmation, see *Van Nostrand's Magazine, N. Y., Aug.* 1882, *page* 154.

Iron to Stone. — Fine iron filings, 20 parts, P' ˈs, 60, and 1; mixed fluid with vinegar, and applied fort

Draught. $\overline{W - w}\, h = D$. W *and w r at external and internal temperatures, h heig .e of draught.* See Weight of Air, page 521.

ɔr India Ink improves with age, sho *t down*, the movement should be in a right

Coal, Effective Value of. Theoretical quantity of heat per IP is 2564 units per hour, and average quantity of heat in a lb. of coal that is utilized in the generation of steam in a boiler is 8500 units; hence, theoretical quantity of coal required per IP per hour $= \frac{2564}{8500} = .3$ lbs., after the water has been heated into atmospheric steam, being theoretically nearly 7.5 per cent. of total heat required to change 30 lbs. water at 60° into steam of 60 lbs. effective pressure.

The total heat developed by the combustion of coal, when utilized evaporatively, ranges from .55 to .8, but in practice it does not exceed 65 per cent.

Coast and Bay Service. A velocity of current of 2.5 feet per second will scour and transport silt, and 5 to 6.5 feet sand. For river scour the velocities are very much less.

Cold, Greatest. —220°, produced by a bath of Carbon, Bisulphide, and liquid Nitrous Acid.

Corrosion of Iron and Steel. The corrosion of steel over iron is, as a mean, fully one third greater.

Cost of Family of Mechanics in France ranges from [illegible] to $600 per annum, of which clothing costs 16 parts, food 61, rent 15, and miscellaneous 8.

Crushing Resistance of Brick. A pressed brick of Philadelphia clay withstood a pressure of 500 000 lbs. for a period of 5 minutes.

Earthwork. *Shovelling.*—Horizontal, 12 feet. Vertical, 6 feet. When thrown horizontal, 12 to 20 feet, 1 stage is required, and from 20 to 30, 2 stages. When vertical, 6 to 10 feet, 1 stage is required.

Wheelbarrow.—Proper distance up to 200 feet.

Number of Loads and Volume of Earth per Day.
One Laborer. (*C. Herschell, C. E.*)

Distance.	Trips.	Volume.	Distance.	Trips.	Volume.	Distance.	Trips.	Volume.
Feet.	No.	Cub. Yds.	Feet.	No.	Cub. Yds.	Feet.	No.	Cub. Yds.
20	120	23.5	150	96	13.3	350	88	11.6
50	110	16.9	200	94	12.8	400	86	11.2
70	100	14.4	250	92	12.4	450	84	10.9
100	98	13.8	300	90	12	500	82	10.5

Volume of a barrow load, 2.5 cube feet.

Portable Railroad and Hand Cars.—For a distance of 550 feet, 60 cube yards can be transported per day.

Horse Cart.—**Volume of Earth transported per Day.**
One Laborer.

Distance.	Trips.	Volume.	Distance.	Trips.	Volume.	Distance.	Trips.	Volume.
Feet.	No.	Cub. Yds.	Feet.	No.	Cub. Yds.	Feet.	No.	Cub. Yds.
300	86	17.1	1000	43	8.6	2000	25	5
500	67	13.6	1500	31	6.4	2500	21	4.3

Volume of each load, 8 cube feet.

Ox Cart is less in cost at expense of time.

Electric Light, Candle Power of. *Maxim Incandescent Lamp.*—Current with 30 Faure cells, 74 volts, 1.81 Ampères, 16 standard candles. With 50 like cells, 124 volts, and 3.2 Ampères, 333 candles. (*Paget Hills, LL.D.*)

The elavated electric lights at Los Angeles, Cal., are distinctly visible at sea for a distance of 80 miles.

[illegible]gine and Sugar Mill, Weights of. ENGINE (*non-condensing*) [illegible]*der.*—30 ins. in diam. by 5 feet stroke of piston. *Boilers* (cylindrical flue)—[illegible] diam. by 40 feet in length. *Weights.*—*Engine*, 105 000 lbs.; *Boilers*, con[illegible] *Sugar-mill*, 40 ins. by 8 feet, 220 050 lbs.; *Connecting Machinery*, [illegible]riers, etc., 46 787 lbs.

ing Stone. *Artificial.*—Clay, 15 parts; Levigated Chalk, 1.5; and , coarse, 83.5. Mixed in water, molded, and hard burned.

ɜngine, Steam. Relative effect for equal cost compared with a ıe, as 1 to 113. Each IHP requires about 112 weight of engine.

.ng Bodies, Velocities of. At low speeds resistance increases less than square of velocity. In a Canal, at a speed of 5 miles per hour, ve is raised, which at a speed of 9 miles disappears, and when speed is that of the wave, resistance of boat is less in proportion to velocity, and is reduced.

f Vessel.—The proper length for a vessel in feet (upon the wave-line ifteen sixteenths of square of her speed in knots per hour.

of Air. $67\sqrt{h}$ = *Velocity per second* × C. *h representing column . ins., and* C *a coefficient ranging from* 56 *to* 100.

ır orifices, thin plate	.56 to .79
rical mouth-pieces, short	.81 " .84
'. do. rounded at inner end	.92 " .93
.l converging mouth-pieces	.9 " 1
lal mouth-piece, alike to contracted vein	.97 " 1

, Corrugated. (*Wm. Parker.*) $\frac{1000\,(T-2)}{D}$ = *Working stress in inch.* T *representing thickness in 16ths of an inch, and* D *diameter in ins.* rrugations 1.5 ins. deep. Experiments upon a furnace 31.875 ins. in , feet in length, and with 13 corrugations.

dation Piles. When piles are driven to a solid foundation, they act s of support, and are designated *Columns*, and when they derive their ; power from the friction of the soil alone, they are termed *Piles*.

ıes differ greatly as to the factor of safety for Piles, varying .1 to .01 of ram. (*Weisbach.*)

nns, their safe load may be taken at from 750 to 900 lbs. per sq. inch. s give a higher value (Rankine and Mahon, 1000); but it is to be borne ıat when piles are driven to a solid resistance, they are frequently split, ıuently their resistance is much decreased.

ɜ, the following *coefficients* for ordinary structures are submitted:

ıe piles are wholly free from vibration consequent upon external impulse, .nd when the structures are heavy and exposed to irregular loading, as s, etc., .15 to .2.

ly, the bearing of a properly driven pile not less than 10 ins. in diam. may t 10 tons.

ion of Bottoms of Vessels. At a velocity of 7 knots per ıl bottom requires 2.42 IP over that for a clean bottom.

ion of Planed Brass Surfaces in muddy water is .4 pressure.

Steam, and Hot-air Engines. Relative costs of gas, steam, ıgines per IP: Otto Gas engine, 8.75; Steam engine, 3.5; and Hot-air

. Available heat per IHP per hour $\Big\}$ = $\frac{16\,431\,535}{\text{Total heat of combustion} \times \text{Coef}}$ =

on of coal per IHP.

000 × 772 units = 10 808 000. Theoretical evaporative

fficiency of furnace = .5; then 10 808 000 × .5 = 5 404 00

. per IHP per hour.

Boats, *Speed of.* Maj.-Gen. Z. B. Tower, U. S. A., assig ıt twice that of the wind, and the angle of sail, to attaiı :han 90°.

ı Coal. *Analysis of Bituminous.*—Specific Gravity, 1 ⁄drogen, 5.28. Oxygen, 3.26. Nitrogen, 2.75. Sulphur, 1 ɔ8.

orative effect = 4.16 lbs. water per lb. of coal.

Lee-way. A full modelled vessel, with an immersed section of 1 to longitudinal section, and with an area of 36 sq. feet of sails to 1 of immen tion, will drift to leeward 1 mile in 6. A medium modelled vessel, with mersed section of 1 to 8, and with like areas of sail and section, will drift 1

Light, Standard of. *Photometric*, English.—Spermaceti candl lb.; 120 grains per hour. Carcel burner = 9.5 candles.

Locomotive Axles, *Friction of*. .016 of weight. Hence, if r wheel = .1, axle friction at periphery $\frac{2240}{60} \div 10 = 3.73$ at periphery.

Mercurial Gauge. To prevent freezing, apply or introduce Gly top of column.

Metal Products of U. S., 1882. Value, $222 000 000.

Mississippi River, Silt in. Near St. Charles the volum borne per day in 1879 was 475 457 cube yards, and on one day, July 4 113 600. At times the volume equals 3 ozs. per cube foot of water.

Motive Power. A sailing vessel having a length 6 times th breadth, requires, for a speed of 10 knots per hour, an impelling force of 4 sq. foot of immersed section.

Mowing Machine. *Kirby's* (Auburn, N. Y.)—670 lbs., 2 hors heavy clover in 46 min.

Ordnance, Energy of. In a competitive test of a 9-inch gun, and a 5.75-inch Krupp, the energy per inch of circumference of bo spectively 118 and 123 foot-tons; their penetration therefore by the wro standard being about the same, but their total energies were respective and 5800 foot-tons.

At Meppen a shot of 110 lbs., with a velocity of 1749 feet per second, an ing energy of 2300 foot-tons, passed through a target composed of two plat wrought iron 7 ins. thick, with 10 ins. of wood between them, and passed beyond.

Petroleum. One lb. crude oil heated 1 lb. water 315.75° = 28.21 at 60° converted to steam at 212°. Relative evaporative effects of Oil and cite coal as 1 to 3.45.

Population, Comparative Density of, and Numl Persons living in a House in different Citie

Chicago, 4; Baltimore and Naples, 4.5; Philadelphia, 6; London, Bo Cairo, 8; Marseilles, 9; Pekin, 10; Amsterdam, 11; New York, 13.5; 17.07; Rome and Munich, 27; Paris, 29; Buda Pesth, 34.2; Madrid, 40; S burg, 43.9; Vienna, 60.5; and in Berlin, 63.

Power of a Volcano. An eruption of that of Cotopaxi has a mass of rock of a volume of 100 cube yards a distance of 9 miles.

Power Required to Draw a Vessel or Load up clined Hydrostatic Rail or Slip Way. (*Wm. Boyd,*

$W\,I = R$; $C\,d\,W \div D = F$; and $P\,d'\,c = f$. W *representing weight of load and cradle*, I *inclination of ways, as length ÷ rise*, R *resistance of vess* F *friction of cradle and rollers, and f friction of plunger in stuffing-box*, *a* C *and c coefficients of friction of cradle and stuffing-box*, d *diameter of axle* d' *product of circumference of plunger and depth of collar or stuffing, all in* P *pressure per sq. inch on plunger, in lbs.*

$$\text{Hence, } W\frac{\text{rise}}{\text{length}} = I, \text{ and } R + F + f = \textit{power in tons.}$$

ILLUSTRATION. — Assume weight of a vessel and cradle 2000 tons, pr plunger 2500 lbs. per sq. inch, inclination of ways 1 in 20, diameters of ax ers and of rollers 3 and 10 ins., depth of collar 2 ins., and circumference o 50; what would be the power required? C = .2, and c = .6.

$$\text{en } \frac{2000}{20} = 100 \text{ tons}; \quad \frac{.2 \times 3 \times 2000}{10} = 120 \text{ tons}; \quad \frac{2500 \times 2 \times 50 \times .6}{2240}$$

$-\!\!\!\!+ 67 = 287$ tons.

Propeller Steamer, Ordinary Distribution of Pov... a. Power developed by engine, 88 IHP; Power expended in its operation,

	Per cent.		Per
Friction of load............	7.5	Power expended by slip of propeller....	
" of propeller........	7.5	" " in propulsion.........	

Pump, *Centrifugal*, has lifted water 28 to 29 feet, drawn it horizontally feet, and then lifted it 15 feet. Also drawn it 24 feet, and projected it 50 feet.

Railway Trains. *Power and Resistance.*—A railway train runnin rate of 60 miles per hour = 88 feet per second, and velocity a body would acq in falling from 88 feet $= \overline{88 \div 8.02}^2 = 120.3$ feet. Consequently, in addition to p expended in frictional and atmospheric resistance to train, as much power mus expended to put it in motion at this speed, as would lift it in mass to a heigh 121 feet in a second.

If the train weighed 100 tons = 224 000 lbs., then 224 000 × 120.3 = 26 74 foot-lbs., and if this result was obtained in a period of 5 minutes, it would req 120.3 ÷ 5 × 224 000 ÷ 33 000 = 163.3 IP in addition to that required for fricti resistances.

To raise the speed of a train from 40 (58.66 feet per second) to 45 (66 feet per ond) miles per hour, the power required in addition to that of friction would b $\overline{58.66 \div 8.02}^2 = 53.44$ feet is to $\overline{66 \div 8.02}^2 = 67.57$ feet $= 67.57 - 53.44 = 14.13$ f

Assume a train of 100 tons, running at rate of 60 miles per hour, and total ret ing power at .1 its weight 100 ÷ 10 = 10. Then 224 000 × 10 × 120.3 = 26 947 2 22 400 = 1203 feet, which train would run before stopping. If, however, train ascending a grade of 1 in 100, the retarding force = .11 (11 ÷ 100) of weigh 24 640, distance in which train would come to rest would be 26 947 200 ÷ 24 6 1093.6 feet.

Relative Non-conductibility of Materials.

Material.	Per cent.	Material.	Per cent.	Material.	Per
Hair felt..........	100	Mineral wool, No. 1	67.5	Lime, slacked	48
Mineral wool, No. 2	83.2	Charcoal.........	63.2	Asbestos.........	36
" " and tar	71.5	Pine wood........	55.3	Coal ashes........	34
Sawdust..........	68	Loam............	55	Air space, 2 ins...	1[illegible]

Resistance to a Steam-vessel in Air and Water. I 10 per cent. of IHP, and in water, at a speed of 20 miles per hour, 90 per cent., IHP per sq. foot of immersed amidship section.

Saws, *Circular*. 30 ins. in diameter, are run at 2000 revolutions per mi = 3.57 miles.

Spur Gear has been driven at a velocity of 1 mile per minute.

Sugar Mill Rollers. 5 feet by 28 ins., at 2.5 revolutions per min requires 20 IP, and 18 feet per minute is proper speed of such rolls.

Surface Condensation, Experiments on. (*B. G. Nichol.*
Tube of Brass, .75 *Inch External Diameter. No.* 18 *B W G. Surface* = 1.
sq. feet. Duration of Experiment, 20 *Minutes.*

Steam.	Vertical.		Horizontal.	
Temperature....................	255°	256°	253°	254°
Pressure per sq. inch per gauge...	17.75 lbs.	18.25 lbs.	16.75 lbs.	17.25
Condensation by tube surface....	18.5835 "	29.9585 "	24.0835 "	43.083
" per sq. ft. of " per hour	52.32 "	84.34 "	67.8 "	121.29
Condensed during experiment....	19.0625 "	30.4375 "	24.5625 "	43.562

Steamers' Engines, Weights of. *Engine, Boiler, Water, and Fittings ready for Service per* IHP.

Mercantile steamer..........	480 lbs.	Light draught...............	280 lb
English Naval "	360 "	Torpedoes...............	

Ordinary Marine Boiler with Water........ 196 lbs.

Wind, Pressure of. *Estimate of, upon Structures.*—30
Per lineal foot of a locomotive train = 10 feet in height, 300 lbs. pe
A Tornado has developed a pressure of 93 lbs. per lineal foot.

The Suez Canal. *Passage by Steamers.*—Ship "Stirling Castle," left Gravesend, in 29 days 21 hours and 27 mins., including 1 day 21 hours [illegible] spent in coaling and detentions.

"*Glenroy,*" Amoy to New York, N. Y., in 44 days and 11 hours, including [illegible] stops at [illegible]. From Gibraltar in 11 days.

Zinc Foil in Steam-Boilers. Zinc in an iron steam-boiler [illegible] forms a voltaic element, which decomposes the water, liberating oxygen and hydrogen. The oxygen combines with fatty acids and makes soap, which [illegible] prevents the adhesion of the salts left by evaporation. The scale [illegible] can then be readily removed.

Piles. *To Compute Extreme Load a Foundation Pile will Sustain.*

$$\frac{W^2 h}{(P+W) \times s} = L.$$

W representing weight of ram, P weight of pile, and L [illegible] *load, all in lbs.; h height of fall of ram, and s distance of depression of pile at last blow, both in feet.*

Illustration.—Assume a ram 1000 lbs. to fall 20 feet upon a pile of 400 lbs.; what resistance will the earth bear, or what weight will the pile sustain [illegible] driven by the last blow, from a height of 20 feet, .5 inch?

$$s = .5 \text{ of } 12 \text{ ins.} = .0416.$$

$$\text{Then } \frac{1000^2 \times 20}{(400+1000) \times .0416} = \frac{20000000}{58.24} = 343\,406 \text{ lbs.}$$

Perimeter. The limits or bounds of a figure, or sum of all its sides. Of a canal it is the length of the bottom and wet sides of its transverse [illegible]

Flood Wave. The flood wave of the Ohio River in March (1884) [illegible] feet 1 inch at Cincinnati, being higher than that of any previous record.

Ice. Crushing Strength of, as determined by U. S. testing machine, [illegible] from 327 to 1000 lbs. per sq. inch.

Atmosphere. If pure air is exhausted of 2.5 per cent. of its oxygen [illegible] not support the combustion of a candle.

Blasting Paper. Unsized paper coated with a hot mixture of [illegible] prussiate of potash and charcoal, each 17 parts; refined saltpetre, 35; [illegible] chlorate, 70; wheat starch, 10, and water, 1500.

Dry, cut into strips, and roll into cartridges.

Circular Saws. Speed, 9000 feet per minute. Thus, for an 8 ins. [illegible] revolutions, and progressively up to a 72 ins., 500 revolutions. (*Emerson.*)

Foods, Relative Value of, compared with 100 Lbs. [illegible] Good Hay.

Additional to page 203.

	Lbs.		Lbs.		
Acorns	68	Linseed	59	Rye	[illegible]
Barley and Rye, mix'd	179	Mangel-wurzel	339	Turnips	[illegible]
Barley straw	180	Pease and Beans	45	Wheat	[illegible]
Buckwheat	64	Pea-straw	153	Wheat, Pea, and [illegible] chaff	[illegible]
Buckwheat straw	200	Potatoes	175		

Depth of the Ocean. Mean depth is estimated by Dr. [illegible] 1827 fathoms = 1.83 geographical miles.

Gas-engine. A gas-engine 1.5 actual HP will cost, with gas at $1 [illegible] hour, 10 cents per hour for 10 hours. (*Am. Engineer.*)

Locomotive. Average daily run 100 miles at a cost of $12 [illegible] fireman, fuel and repairs. (N. J. Central R. R. Co.)

Consumption of Fuel per Mile. Passenger, 25 to 30 lbs. coal. Freight, [illegible] lbs., or one cord wood per 40 miles.

.ry. In laying stones in mortar or cement, they should rest upon the ath them, more than upon the material of joint.

Gun (Krupp's). Bore, 15.75 ins.; length of bore, 28.5 feet; of 'eet. Weight, 72 tons. Charge, 385 lbs. prismatic powder; projectile, 1660 lbs., with an explosive charge of 22 lbs. of powder.

of shot at muzzle, estimated at 31 000 foot-tons, and range 15 miles.

Mill. *7722 feet of 1 inch Poplar boards in One Hour.*

[on-condensing). *Cylinder.*—12 by 24 ins. stroke of piston.

Two (cylindrical flued), 38 ins. in diam. by 26 feet in length, two 14 ins. in each. *Heating Surface.*—780 sq. feet. *Grates.*—42.5 sq. feet.

of Steam.—125 lbs. per sq. inch, cut off at 16.5 ins.

ns.—250 to 350 per minute. *Saws.*—Two circular, 60 and 66 ins. in

Grates set 28 ins. from under side of boilers, without bridge-wall, and a chamber under boilers, 4 feet in depth. Fuel, sawdust.

Heating. 62 500 cube feet of space requires 6000 sq. feet of heat- to attain a temperature of 70° in the vicinity of the city of New York st weather.

q. foot of iron pipe will heat 10.5 cube feet of space in an ordinary build- ature of exterior air 70°. (*Felix Campbell.*)

ty of Steam. Steam at a pressure of 60 lbs. + atmosphere has f efflux of 890 feet per second, and as expanded, a velocity of 1445 feet.

ng. In small blasts 1 lb. powder will detach 4.5 tons material, and in 2.75 tons. (See page 443.)

Metal (Iron and Bronze). Specific gravity 8.4. Melting point 1800°. 34).

1 Wood of Australia. Impervious to insects and the *Teredo*

al Gas and Bituminous Coal. Relative water evaporat- Gas, 20 to 21 lbs. Coal, 9 lbs.

Board of Vessels. For each foot of depth of hold (from ceiling le of main deck), .1 inch added to 1.5 ins. for a depth of 8 feet. Thus, lepth $1.5 + .1 \times \overline{8 \infty 24} = 3.1$ *ins.* (*American.*)

for 8 feet depth and .1 for each foot in addition thereto. (*Lloyd's.*)

Colors for Working Drawings.

..Gamboge.	Steel ......Neutral tint, light.
..Carmine.	Water .....Cobalt.
..Burnt Umber.	Wood......Burnt Sienna.
..Sepia with dark markings.	Stones and Earths .. { Burnt Umber.
..Lake and Burnt Sienna.	Yellow Ochre.
..India Ink, light.	" "
..Neutral tint.	"
t.Prussian Blue.	Red and
..Ind. Ink tinged with P. Blue.	Burnt Si

ge of Chain Cable. Square of diameter o 35 will give volume of space required to stow 1 fatho

lt Mortar. Bitumen 1 part, powdered asphalt 7. esin oil .28 part.

men, add asphalt broken small, than resin oil and sand.

lt Concrete. Asphalt mortar 11 parts and broken

tos is a fibrous variety of Actinolite or Tremolite, comp agnesia, oxide of iron, and water. It resists heat, moist

Daily Food of an Esquimau. Flesh of a sea-horse 8.5 and Bread 1.75 lbs., Soup 1.25, Spirits 1, and Water .9 pint. (*Sir W. E. Parry.*)

Coignet's Concrete. *For walls that resist moisture.*—Sand, Gravel, and Pebbles, 7 parts; Argillaceous Earth 3 parts, and Quicklime 1 part.

Hard and quick setting.—Sand, Gravel, and Pebbles, 8 parts; Earth, burned and powdered Cinders, each 1 part, and Unslacked hydraulic Lime 1.5 parts. For a very hard mixture, add cement 1 part.

Transmission or Conductivity of Temperature in the Earth. At Edinburgh thermometers set at a depth of 16 feet in the earth attained their maximum and minimum at about six months after the corresponding maximum and minimum of the surface, being lowest or coldest in July.

The average rate of transmission of heat, as observed at Schenectady, N. Y., was, downwards, 2.9 feet per month, and upwards 3.4 feet. (*Olin H. Landreth.*)

Shafts. When loaded transversely, the diameters of the journal should first be determined, its dimensions then at any other point can be deduced from those diameters. It being observed that the diameters at any two points should be proportional to the cube roots of the stress at those points.

Journals.—For operation at high speed a greater length is required than for low speed. The less their length, the less may be its diameter for a given stress, and consequently the friction will be less.

When in constant operation, a large surface is required to reduce heating, and as friction increases with diameter, not with length, for like stress, it is best to lengthen.

Wrought Iron. — For 50 revolutions length to diameter as 1.2 to 1, and for every 50 revolutions additional .2 should be added. Thus, for 1000 revolutions the length to diameter should be 5 times. *Cast Iron.* — Length to diameter as .9, and *Steel* as 1.25 of above value. (*W. C. Unwin.*)

Non-conducting Materials. By the investigations of Prof. J. M. Ordway of New Orleans, he determined the relative non-conducting values of the following materials, compared with a naked pipe, to be:

Hair-felt, burlap	1	Cork in strips	2
Asbestos paper, hair-felt, duck	1.18	Rice-chaff	2.2
Pine charcoal	1.26	Clay and vegetable fibre	2.8
Air space	4	Naked pipe	31

(*Engineering*, *vol.* 39, *page* 206.)

Marine Transportation of Troops. Height between decks (deck to under side of beam), men 6 feet, horses 7 feet. *Hatchways.*—Horses at least 10 by 10 feet. *Vessels.*—Horses, beam not less than 30 feet. Men, all ranks, 2 to 2.5 tons capacity; horses, 10 tons. *Rations.*—If biscuit in bags, 10 000 require 950 cube feet of volume; if it is in barrels, 1350 cube feet.

Cabins.—Officers, 30 sq. feet and 195 cube feet of volume, two men 42 sq. feet, and 270 cube feet of volume, and for each additional man 10 sq. feet, exclusive of bed space of 6 by 2 feet.

Hammocks.—To compute number that can be swung under a deck.

$\times \frac{b}{.5} = n.$ *l representing length under deck in feet, and b breadth in in*

ley.)

of Boilers.—30 lbs. water evaporated into dry nder a pressure of 70 lbs. per sq. inch mercurial gauge. 34.5 lbs. water as above from feed at 212° into steam Engineers.)

Penetration of Light in Water. Mediterranean, clear sunlig In March, at a depth of 1200 feet; in winter, 600 feet. (*M. M. Fol and Sarasin.*)

Railroad. *Horse.* First in operation in 1826–7.

Pins. First in use in England about 1450.

Iron Steamers. First build in 1830.

Lucifer Match. First made in 1829.

Watches. First constructed in 1476.

Load on Stone *per sq. foot.* Church of All-Saints at Angers, 86 000 l Pantheon at Rome, 60 000 lbs.

Flexible Paint for Canvas. Yellow soap 1.66 parts. Boil water 1. Grind while hot with .83 parts oil paint.

Fuel. Evaporation of 9 lbs. water from 212°:

1 lb. good coal.	.75 lb. petroleum.
2 lbs. dry peat.	2.5 lbs. dry wood.
3.25 " cotton stalks.	3.5 " brush wood.
3.75 " wheat straw.	4 " megass, or cane refu

Tramways or Street Railroads.

Resistance on straight and level tracks 15 to 40 lbs. per ton, or an average 30 lbs.

Power required on a good track to start a car, as determined by A. W. Wrig M.W.S.E., 116.5 lbs., and to maintain it in motion 17.2 lbs. C. E. Emery, Ph. made it 13 lbs. On a bad track, the power is 134.6 lbs. to start, and 35 to maint it in motion.

Power required, as determined by Mr. Wright, to start a car is 33.53 HP, with average load and day's work, and 133.22 to maintain it in motion.

Average work of a car-horse 5.75 hours per day for a term of service of 6 yea Strong draught-horses will exert a power of 143 lbs. @ 2.75 miles per hour for miles, and an ordinary one 121 lbs. for 25 miles. (*Gayffier.*)

Cable Railway. Mr. Wright gives the power required per ton * at 1.92 HP.

* All tons here and elsewhere are given at 2240 lbs.

Result of Experiments on Motors for Street Railroad (1885.)

At Antwerp, by Capt. D. Galton, F.R.S., etc.

1. Locomotive Engine and Car. Ordinary type of steam-engine, surface conden (*Krauss*).
2. " " Surface condenser, vertical boiler, escape su heated (*Black and Hawthorn*).
3. " " Compound engine, compressed air, water-t boiler (*Beaumont*).
4. " " and car combined. Ordinary type of steam-engine, wa tube boiler (*Rowan*).
5. " " " combined. Electric Fausse Batteries.

Weight of Train per Passenger.	Fuel consumed Per Mile of Course.	Fuel consumed Per Seat per Mile of Course.	Oil, Tallow, etc.	Water per Mile of Course.
Lbs.	Lbs.	Lbs.	Lbs.	Gallons.
5. Electric....1.78	4. Rowan.......5.22	.1	.038	Rowan.....
4. Steam......2.3	5. Electric......6.16	.23	.038	Comp'd air.1
3. Comp'd air, 2.55	2. Black and Hawthorn.. 8.82	.23	.073	Black and Hawthorn 5
	1. Krauss 9.1	.25	.101	Krauss.....6
	3. Comp'd air..39.48	.66	.255	

Note.—The economy of the Rowan motor occurred mainly from the extent of its cond power, by which warm water was supplied to the boiler.

Corrosive Effects of Salt-water on Steel or Iron.

(*J. Farquharson.*)

Loss of Plates Submerged for Six Months. Area 12 Sq. Feet.

Steel	.253 lb.	Steel	combined	.07 lb.
Iron	.233 "	Iron	combined	.445 "

Frictional Resistance of a Railway Train. (*C. H. Hudson.*)

Resistance per ton, due to atmosphere at maximum speed, .132 lb.; to start, 17.27 lbs.; and to maintain in motion, 5.1 lbs.

Blasting Gelatine. (*G McRoberts, F.C.S.*)

Is composed by weight....	Nitro-glycerine......	93 parts	Effective power.... 1400 foot-lbs.
	Nitro-cotton.........	7 "	

It freezes hard at a low temperature (35 to 40°). At ordinary temperature above freezing, it does not explode by shock, but when frozen it readily explodes. It is insoluble in water Specific gravity 1 55 to 1 59.

Effective Power of some other Explosives.

Nitro-glycerine, 1270 foot-lbs.; Dynamite, No 1, 900; Gun-powder, extra strong, as Curtis and Harvey's, 272; Dynamite, No. 2, of 18 nitro-glycerine, 71 nitrate of potash, 10 of charcoal, and 1 of paraffin, 531, and Fulminate of Mercury, 367.

Bolts of Wrought Iron as Affected by the Thread.

(*D. K. Clark.*)

Strength per Square Inch of Metal.

Diam. of Bolt.	Tool.	Strength when cut.	Loss.	Diam. of Bolt.	Tool.	Strength when cut.	Loss.
Ins.		Lbs.	Per cent.	Ins.		Lbs.	Per cent.
1.25	Dies.*	40 812	25	1	Chaser.	44 845	28
1.25	Chaser.	38 528	29	.625	Old Dies.	51 005	14
1	Old Dies.	55 149	11	.625	New Dies.	43 613	26
1	New Dies.	42 650	30	.625	Chaser.	41 833	33

* Die not given, evidently new.

Approximate Bottom Velocities of Flow of Water in Channels, at which following Materials begin to Move.

(*Haupt.*)

Feet.	Miles.		Feet.	Miles.	
Sec.	Hour.		Sec.	Hour.	
.25	.17	Microscopic sand and clay.	3	2.04	Small stones, 1.75 inch in diam.
.5	.34	Fine sand.			
1	.68	Coarse sand and fine gravel.	3.33	2.3	Flint stones, size of hen's eggs.
1.75	1.19	Pea gravel.			
2	1.39	Rounded pebbles, 1 inch in diam.	5	3.41	2-inch square brick-bats.

Scouring force of the current is proportioned to the *square of its velocity.*

Transporting capacity varies as *sixth power of the velocity.* Hence the importance of increasing *bottom* velocities, both to effect a scour and to prevent deposits.

Chimney. (*Metternick Lead Mining Co.*)

Foundation 36 feet square by 11.5 in height; base circular 24.6 feet by 39.37 in height; shaft, 397.5 feet in height, 24.6 feet at base, and 12.48 at top; flue 12.48 and [illegible] feet in diameter. Total height 441.6 feet.

Evaporation of Water. *Mean, as observed at Boston, Mass.*

	Ins.		Ins.		Ins.		Ins.
[illegible]	[illegible]	April........	3.1	July.........	6.28	October......	2.95
[illegible]	[illegible]	May..........	4.61	August.......	5.49	November....	1.63
[illegible]	[illegible]	[illegible].........	5.86	September...	4.09	December....	1.2

Total.................. 39.11 ins.

Central Width of a Roadway in a Cut.

	Feet.		Feet.
ʼ, single line	18 to 20	Public road	28 to 30
double line	30 " 33	Turnpike road	38 " 40

Hydraulic Ram.

cy under Heads of Supply from 2 to 24 Feet, and Delivery of Discharge at Elevations from 15 to 100 feet.

Measurements from Valves of Ram.

ʼompute Per Cent. of Total Volume of Water Expended.

$=$ *Per cent.* H *representing head of supply, and* E *elevation of discharge,* *feet, and* C $= .8$.

ɪTRATION. — What is volume of water delivered with a head of 21 feet to an ɔn of 60 feet?

.8 = .28 *per cent.* Hence, if the volume of discharge is 100 cube feet, vol- evated is $100 \times .28 = 28$ *cube feet.*

ʼ*sely.* By formula of E. B. Weston, M. Am. Soc. C. E.

[= V. S *representing number of cube feet expended in ram per minute, h dif-* ː *in elevations of ram and delivery in feet, and* V *volume raised in cube feet.* to 70.

me as preceding, H = 21 feet, E = 60 feet, and S = 100 cube feet.

$$\text{Then, } \frac{100 \times 65 \times 21}{100 \times \overline{60 - 21}} = \frac{136\,500}{3900} = 35 \textit{ cube feet.}$$

.—To conform to the preceding formula C should be 52.

To Compute Elements of a Screw Propeller.

$$\frac{l\,a}{\text{ɔ}} = \text{T}; \quad \frac{\text{P}\,2\,l\,a\,\text{R}}{p\,\text{R}} = \text{T}; \quad \frac{\text{P}\,2\,l\,a\,\text{R}}{33\,000} = \text{IHP}; \quad \text{and} \quad \frac{\text{IHP}\,33\,000}{p\,\text{R}} = \text{T}.$$

ɔ*resenting mean pressure on piston per sq. inch in lbs., a area of piston in sq. pitch of propeller and l length of stroke, both in feet,* R *number of revolutions* ː*nute, and* T *thrust of propeller in lbs.*

STRATION.—The elements of operation of a steam-engine are: Mean pressure ːon, having an area of 1000 sq. ins., is 30 lbs.; length of stroke 2 feet; revolu- ɪf engine 130 per minute; and pitch of propeller 12 feet. What is the thrust propeller, and what the power of the engine?

$$\frac{\times 2 \times 1000}{12} = 10\,000 \textit{ lbs.}, \text{ and } \frac{30 \times 2 \times 2 \times 1000 \times 130}{33\,000} = \frac{15\,600\,000}{33\,000} = 472.7 \text{ IHP}.$$

Centrifugal Pump.

(Southwark Foundry and Machine Co. Non-condensing.)

ɪ*ps.*—Two of 42 ins., with runners 68 ins. in diameter; dis-
ines.—Two of 28 ins. in diameter of cylinder, and 24 ins. st
ers. — 12 Horizontal tubular. *Heating surface,* 8568 sq. ft
Combustion natural.
sure of Steam 70 lbs. per sq. inch, cut off at .625.
lutions, 130 to 160 per minute.
ht of Delivery, 0 to 36 feet.
ht.—Pumping plant exclusive of boilers 300 000 lbs.
harge.—From Dry-dock from a depth of water of 0 to 36 feet
ɪ*gas* gallons.

Friction of a Non-condensing Engine. (*Prof. R. H. Thurst*

Friction of a non condensing engine is given at from 2 to 4.75 lbs. per sq. inch of piston, being least at low pressure. The conclusions drawn from a series of experiments are as follows:

1. It is sensibly constant at any given speed of engine at all loads.
2. It is variable with variation of speed of engine, increasing with the speed.
3. It increases with increase of pressure of steam.

NOTE.—This per cent. of friction is somewhat less than that given ante at p. 733.

Visibility of Vessel's Sidelights. The minimum distance of visibility assigned by the International regulations for green and red lights is nautical miles.

Weight of Anvils. The weight of an anvil for forging iron should be 8 times that of the hammer, and for steel 12 times. (*Prof. Friedrich Bick.*)

Temperature of Mines. Temperature of copper-mines of Lake Superior increases 1° for every 100.8 feet of depth. The usual gradient is from 50 to 55 feet. (*H. A. Wheeler.*)

Horse. In transportation by sea occupies the space of 10 tons measurement, and requires that of 300 cube feet of air.

Stalls 6 feet in length in the clear of padding and haunch piece, 2 feet 2 ins. in clear width between padding, 10 per cent. of this width 2 ins. narrower, and 5 per cent. of it 6 ins. longer.

Mule. A pair will draw, including cart, 1500 to 2000 lbs.

Ass. Will carry 100 to 200 lbs. 15 miles per day.

Camel. The Arabian, or Dromedary, has one hump on back, the Bactrian has two. Large animals will carry 1500 lbs. for 3 or 4 days, or 1000 lbs. for several days, and 450 to 600 lbs. for a long march.

One has travelled 115 miles in 11 hours.

Elephant. Weight, 3 to 5 tons; weight one can carry about 1450 lbs.; 3000 lbs. have been carried. Occupies 55 sq. feet; will travel on a good road at a rate of 2.5 miles per hour for 6 hours.

Whales. Greenland Right, length 50 to 60 feet. Finner, 80 feet. Speed, 8 to 12 miles per hour. Extreme weight, 74 tons. HP estimated at 145.

Chimneys. Late experiments as to the draught of chimneys have developed the result that an increase of its area near to the top increases the draught.

Cost of Maintenance of Street Railroads, 1876.

Average of 16 *roads*, 102 *miles in length, with* 1297 *cars and* 10 300 *horses.* (*H. Haupt.*)

Cost per horse, and average number to a car eight.

Repairs of harness	$ 4.06	Shoeing	$22.77
Feed	124.39	Stall expenses	42.13
Replacing horses	22.1		
		Total	$215.46

Cost per month of each horse, $ 18. On one of the longest railroads in the City of New York, on the least populous route, the daily cost per passenger, exclusive of general expenses, was 2.88 cents, and inclusive of general expenses 4.1 cents.

Magnesia Covering for Steam-pipes and Boilers.

…ments made by Bureau of Steam Engineering, U.S.N., developed the following comparative results:

100 | Sectional magnesia.... 103.07 | Sawdust.....

APPENDIX.

River Steamboat. Wood Side Wheels.
Freight and Passenger.

rona."—Horizontal Lever Engines (*Non-condensing*).—*Length on deck*, 10 *ins.*; *beam*, 43 *feet* 4 *ins.*; *hold*, 6 *feet*. *Tons*, 993.52.

·sed section of light draught of 26 *ins.*, 83 *sq. feet*. *Capacity for freight*, 1200 o *lbs.*).

lers.—Two of 25 ins. in diam. by 8 feet stroke of piston.

s.—Four of steel, 47 ins. in diam. by 30 feet in length, 6 flues in each. *surface*, 903 sq. feet. *Grate surface*, 98 sq. feet.

ure of Steam, 154 lbs. per sq. inch, cut off at .625.

utions,——per minute. *Speed*, 10 miles per hour against current of upper :o 5 miles.

'o Compute Meta-centre of Hull of a Vessel.

Operation of Formula in Naval Architecture, page 660.

ie a sharp-modelled yacht, 45 feet in length, 13.5 feet beam, and 9.5 feet th an immersed amidship section of 42 sq. feet, and a displacement of 900 t at a mean draught of water of 6 feet.

$$\frac{2}{3}\int\frac{y^3\,dx}{D} = \textit{Meta-centre.}$$ See pages 650, 659.

ates (dx) taken at intervals of 2.5 feet are as follows:

$= 0 = .0$	$y8^3 = 6.5^3 = 287.496$	$y16^3 = 3.25 = 34.328$
$= .6^3 = .216$	$y9^3 = 6.7^3 = 300.763$	$y17^3 = 2.4 = 13.824$
$= 1.3^3 = 2.197$	$y10^3 = 6.75 = 307.547$	$y18^3 = 1.5 = 3.375$
$= 2^3 = 8$	$y11^3 = 6.5 = 287.496$	$y19^3 = .8 = .512$
$= 2.8^3 = 21.952$	$y12^3 = 6.25 = 244.14$	$y20^3 = 0 = .0$
$= 3.6^3 = 46.656$	$y13^3 = 5.8 = 195.112$	2272.814
$= 5^3 = 125$	$y14^3 = 5 = 125$	2.5
$= 5.8^3 = 195.112$	$y15^3 = 4.2 = 74.088$	5682.035

iation of function of cubes of ordinates for value of $\int y^3\,dx = 5682.035$.

$$\text{And } \frac{2}{3} \text{ of } \frac{5682.035}{900} = \frac{2}{3} \text{ of } 6.31 = 4.21 \textit{ feet.}$$

—The other elements of this vessel are:

of load-line, 401.12 *sq. feet*; *Displacement in weight*, 27.974 *tons*; *do. at load-* ', .955 *tons per inch*; *Depth of centre of gravity of displacement below load-* 19 *feet*; *Volume of displacement, to volume of immersed dimensions*, 26.8 *t.*

'ompute Height of Jet in a Conduit Pipe from a Constant Head. (*Weisbach.*)

$$\frac{h}{C + C'\frac{l}{d}\Big)\left(\frac{d'}{d}\right)^4} = \frac{v^2}{2g} = h', \text{ and } \frac{h'}{z} = h''.$$ *h*, *h'*, *and h'' representing heights*

elocity of efflux, loss of head and of ascent, l length of pipe or conduit, and d diameters of pipe and jet, all in feet, v velocity of efflux in feet per second, C coefficients of friction of inlet of pipe and outlet, and z a divisor determined riment with diameters of .5 *to* 1.25 *ins.*, *ranging from* 1.06 *to* 1.08.

TRATION.—If conduit pipe for a fountain is 350 feet in length, and 2 ' er, to what height will a jet of .5 inch ascend under a head of 40 fe

ne C and C' .8 and .5, $h = 25$ *feet*, $d = 2$ *ins.* $= .166$, and $.5 = .5 \div 1$

$$\text{Then } \frac{25}{1 + \left(.8 + .5\,\frac{350}{.166}\right)\left(\frac{.0416}{.166}\right)^4} = 4.9 \text{ feet.}$$

To Compute Head and Discharge of Water in Pipes Great Length.

It becomes necessary first to determine the velocity of the flow, which i $\frac{4\,V}{3.1416\,d^2} = v = 1.273\ \frac{V}{d^2}$, independent of friction. *V representing volume of in cube feet, and d diameter of pipe in ins.*

When head, length, and diameter of pipe are given, $\frac{\sqrt{2\,g\,h}}{\sqrt{1+C+c\frac{l}{d}}} = v$.

Coefficients of friction C, for velocity of flow, range from .0234 to .0191 for ve ties from 3 to 13 feet per second, and c that for the pipe as a mean at .5. See W bach's Mechanics, Vol. I., page 431.

ILLUSTRATION.—What head must be given to a pipe 150 feet in length and 5 i in diameter, to discharge 25 cube feet of water per minute, and what velocity it attain at that head? $C = .024$ and $c = .5$.

Then $1.273\ \frac{25 \times 12^2}{60 \times 5^2} = 1.273 \times 2.4 = 3.055$ *feet velocity per second*, and

$$\left(\overline{1+.5}+.024\ \frac{150 \times 12}{5}\right)\frac{3.055^2}{64.33} = 1.5 + 8.64 \times .14 = 1.21 \textit{ feet head.}$$

Or, $4.72\ \frac{\sqrt{d^5}}{\sqrt{l \div h}} = V$ *in cube feet per minute*, and $.538\ \sqrt[5]{\frac{l\,V^2}{h}} = d$ *in ins.*

ILLUSTRATION.—Assume elements of preceding case.

Then $4.72\ \frac{\sqrt{3125}}{\sqrt{150 \div 1.42}} = 4.72 \times \frac{55.9}{10.28} = 25.67$ *cube feet*, and $.538\ \sqrt[5]{\frac{150 \times 25.6}{1.42}}$ $= .538 \times \sqrt[5]{69\,607} = .538 \times 9.301 = 5$ *ins.*

To Compute Fall of a Canal or Open Conduit to Conduct and Discharge a Given Volume of Water pe Second.

Coefficient of friction in such case is assumed by Du Buat and others a .007 565.

$C\ \frac{l\,p}{A} \times \frac{v^2}{2\,g} = h$. *h representing height of fall, l length of canal, and p net perimeter, all in feet; A area of section of canal in sq. feet, and v velocity of flow in fe per second.*

ILLUSTRATION 1.—What fall should be given to a canal with a section of 3 feet at bottom, 7 at top, and 3 in depth, and a length of 2600 feet, to conduct 40 cube feet of water per second?

$C = .0076$, $p = 3 + (\sqrt{3^2+2^2} \times 2) = 10.21$ *feet*, $A = \frac{\overline{7+3} \times 3}{2} = 15$ *sq. feet*, and

$v = \frac{40}{15} = 2.66$ *feet.*

$$\text{Then } .0076\ \frac{2600 \times 10.21}{15} \times \frac{2.66^2}{64.33} = 13.45 \times .11 = 1.48 \textit{ feet.}$$

—What is volume of water conducted by a canal, with a section of 4 feet at bottom, 12 at top, and 5 in depth, with a fall of 3 feet, and a length of 5800 feet?

$\frac{A}{\overline{\ \ }} \times 2\,g\,h = v$. $A = \frac{\overline{12+4} \times 5}{2} = 40$ *sq. feet*, and $p = 4 + (\sqrt{5^2+4^2} \times 2) =$

$$\frac{40}{5800 \times 16.8} \times 64.33 \times 3 = \sqrt{\frac{40}{740.544} \times 193} = 3.23 \textit{ feet, and}$$

$= 129.2$ cube feet.

...verse profile of a canal, see Weisbach, page 492, ...

:AGNESIA COVERING FOR STEAM BOILERS, HEATED PIPES, ETC.

Robert A. Keasbey & Co., New York.

s covering is devoid of organic matter, hence it possesses great capacity ist a high temperature, combined with high rank in the order of non-ctors.

s furnished for pipes in the form of hollow cylinders divided longitu-y, and covered with canvas; for boilers, in blocks; and for covering ttings, filling floors, etc., in dry mass in barrels.

ADJUSTABLE-POP SAFETY-VALVES. (Crosby's.)

	INCHES.								
ter of Valve .	1	1.25	1.5	2	2.5	3	3.5	4	5
ty in HP.....	10	20	30	50	80	100	150	200	300

STEAM SIPHON. **An Independent Lifting Pump.**

Capacity for a Discharge Pipe 2 Ins. in Diameter, per Minute.

er raised.		Pressure.	Discharge.	Water raised.		Pressure.	Discharge.
.	Ins.	Lbs.	Gallons.	Feet.	Ins.	Lbs.	Gallons.
	6	30	63.54	13	2	60	119.68
	2	40	85.71	13	2	70	138.44
	2	50	100	13	2	80	157.57

DISTANCES, VELOCITIES, AND ACCELERATION.

'o Compute Velocities of an Accelerated Body.

$\overline{+ (2\,v'\,S)}$, Or, $v + \overline{t\,v'} = V$. *v and v' representing original and accelerated 'es, and V final velocity, all in feet per second; S distance or space passed over , and t time in seconds.* $\frac{v+V}{2} = V'$. *V' representing average velocity in r second.* $V'\,t = S$, and $2\,V' - V = v$.

STRATION I.—A body moving with a velocity of 10 feet per second, is acceler-t rate of 4 feet per second, per second, for a period of 6 seconds; what are its nt velocities?

10, $v' = 4$, $t = 6$.

1, $10 + \overline{6 \times 4} = 34$ *feet final velocity.* $\frac{10+34}{2} = 22$ *feet average velocity.*

$= 132$ *feet distance passed over.* $\sqrt{10^2 + (2 \times 4 \times 132)} = \sqrt{1156} = 34$ *feet,* $\times\ 22 - 34 = 10$ *feet original velocity.*

, $\frac{V-v}{t} = v'$, $\frac{V+v}{2} \times t = S$, $\frac{V^2-v^2}{2\,t} \times t = v'\,S$, $v^2 + 2\,v'\,S = V^2$,

$= t$, and $\sqrt{V^2 - 2\,v\,S} = v$.

A body is projected vertically with a velocity of 200 feet per second, and is ed at the rate of 30 feet per second, per second; what height will it have . through when its velocity is reduced to 80 feet per second, and in what time?

200, $v' = 30$, and $V = 80$.

Then $\frac{200-80}{30} = 4$ *seconds.* $\frac{80+200}{2} \times 4 = 560$ *feet.*

A vehicle being drawn with a velocity of 25 feet per second, is ' per second, per second; what is its velocity and time of operatio feet?

25, $v' = 5$, and $V = 100$.

Then $\frac{100-25}{5} = 15$ *seconds.* $\frac{100+25}{2} \times 15 = 937.5$ *feet.*

[illegible] stream of water, after flowing a distance of [illegible] feet, is ascertained [illegible] velocity [illegible] feet per second, with an accelerating velocity [illegible] per second. What was its [illegible] velocity and time of flow?

[illegible]

Then [illegible]

Delivery and Friction in Hose.

[illegible]

[illegible]

[illegible]

For [illegible] see page [illegible]

[illegible]

[illegible]

Metric Factors. *In addition to pp. 27-37.*

By Act of Congress, July, 1866. | *By French Metric Computation.*

Measures.

Liter per cube meter = .007 48 *gallons per cube foot* ...	.007 48 *gallons.*

Weights and Pressures.

Centimeter of mercury per sq. inch = .192 91 *lb. per sq. inch*	.192 911 7 *lb.*
Atmosphere (14.7 lbs.) = 6.6679 *kilograms*	6.6678 *kilograms.*
Inch of mercury per sq. inch = 2.54 *centimeters*	2.54 *centimetres.*
Pound per sq. inch = 453.6029 *grams*	453.5926 *grammes.*
Cube foot per ton = .0279 *cube meter*	.0279 *cubic metre.*

Heat.

Caloric per Kilogram = 1.8 *heat units per lb.*	1.8 *heat units.*

Velocity.

Meter per second = 3.280 833 *feet per second*	3.280 869 *feet.*

Power and Work.

Kilogrammeter ($k \times m$) = 2.2046 × 3.280 83	7.233 *foot-lbs.*
Foot-pound = .138 26 *kilogrammeters*	.138 25 *kilogrametre.*
Kilogram per cheval = 2.2352 *lbs. per* IP	2.2353 *pounds.*
Sq. foot per IP = .091 63 *sq. meter per cheval*	.091 63 *sq. metre.*

Miscellaneous.

1 Avoirs Lb. =	.4536 *kilogram.*	1 Sq. Foot	= .092 903 *sq. meter.*
1 Ton =	1.016 057 *tonne.*	1 Cube Foot	= .028 317 *cube meter.*
1 Sq. Inch =	645.161 29 *sq. mill'rs.*	1 Cube Yard	= .764 559 *cube meter.*

1 Mile per hour	= 26.8225 *meters per minute.*
1 Knot " " (6086.44 feet)	= 30.9192 " " "
1 Cube Meter per minute	= 7.848 *cube yards per hour.*
1 " Yard " "	= 45.8718 " *meters* " "

Locomotive Brakes. $\frac{v^2}{64.4 f}$ and $\frac{V^2}{30 f}$ = *distance in which a train is* [st]*opped.* *v and* V *representing velocity in feet per second, and miles per hour, and* [p]*roportion of resistance of brakes to weight of train.*

Brakes, self-acting, on all wheels, $f = .14$. Ordinary hand, $f = .023$ to .031. As[cen]ding 1 in .5 resistance is $f + 2$; descending 1 in .5 $f - 2'$.

Hydraulic Rams. Efficiency decreases rapidly as height to which water [is] to be raised increases above the fall or head.

Number of times the height to which the water is raised exceeds that of the head [of] the supply and efficiency per cent. (*Walter S. Hutton, C. and M. E.*)

[N]umber ...	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20	25
[E]fficiency ..	75	72	68	62	57	53	48	43	38	35	32	28	23	17	15	12	0

Speed of water in pumps, 200 feet per minute.

To Compute Weight of Water at any Temperature

$$\frac{2w}{\frac{T + 461.2^\circ}{500} + \frac{500}{T + 461.2^\circ}} = W.$$ W *and w representin*[g] ... [wa]*ter per c*[ube] [foot] *at temperature* T, *and at maximum density of* 39 ... [e]*qual absolute temperature.*

ILLUSTRATION.—Required weight of a cube foot of wa[ter] ...

$$\frac{62.425 \times 2}{\frac{60 + 461.2}{500} + \frac{500}{60 + 461.2}} = 62.37$$

Results of Experiments or Performances of Steam-engines and Boilers.

Cylinders, Cut-off, Vacuum, and Diameters in Inches, Revolutions per Minute, Pressure, Water, and Coal in Lbs., and Surfaces and Areas in Sq. Ins.

Elements of Engine.	Harris. Non-condensing.	Corliss. Condensing.	Corliss. Condensing.
Cylinder	18×42	18×42	24×60*
Revolutions	74.29	73.6	59.62
Pressure in Pipe	58.5	76.37	92.88
Cut off	4.74	7.94	18.02
Mean effective Pressure	26.93	29.47	89.38
IHP	105.47	115.43	270.58
Friction HP	12.64	13.07	12.55
Net HP	92.83	102.36	—
Water per net HP per hour	18.59	25.39	—
Coal per do.	2.34	3.18	—
Coal per IHP per hour	2.07	2.82	1.98
Vacuum	21.83	—	26.4
Combustible per IHP per hour	—	1.83	1.83
Relative efficiency	—	.753	—

Boilers.	
Number	2
Diameter	60
Length	12
Tubes 50	4
Heating Surface	1536.7
Grate "	51.75
Calorimeter	1256.04
Heating to Grate	29.7
Grate to Calorimeter	5.93
Temperature of Feed	114.5
Steam per Lb. of Combustible†	8.35
Steam per Lb. of Coal	8.21
Coal per Sq. Foot of Grate per hour	10.3
Steam per Temp. 212°	9.54

* Weight of engine, 40 000 *lbs.* † Steam per lb. of coal 8.21 *lbs.*, and evaporation 9 to 1.

WINDMILLS. (Andrew J. Corcoran, *New York.*)

(Improved. Patented June and August, 1888; March and June, 1889.)

Volume of Water Pumped per Minute.

From 10 *to* 200 *Feet.*

Diameter of Wheel.	Vertical Distance from Water to Point of Delivery in Feet. 10	15	25	50	75	100	150	200
Feet.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
8.5	15.242	10.162	6.162	3.016				
10	48.262	32.175	19.179	9.563	6.638	4.25		
12	86.708	57.805	33.941	17.952	11.851	8.485	5.68	
14	111.665	74.443	45.139	22.569	15.304	11.246	7.807	4.993
16	155.982	103.988	64.6	31.654	19.542	16.15	9.771	8.075
18	249.93	159.954	97.682	52.165	32.513	24.421	17.485	12.211
20	309.604	206.403	124.95	63.75	40.8	31.248	19.284	15.993
25	532.517	355.012	212.381	106.964	71.604	49.725	37.349	26.741
[illegible]	1080.112	728.828	430.848	216.172	146.608	107.712	74.8	54.043

Velocity of Wind.

…e over the United States, as determined by the Signal Service of the … 69 miles per month, or about 8 miles per hour.

… determined that, to operate a windmill, there is required a … wind of six miles per hour.

… pressure of wind per sq. foot of surface in lbs.

… senting velocity of air in feet per second, and …

… Mover," by A. R. Wolff, …

Compute Head in Lbs. per Sq. Inch to Resist Friction of Air in Long and Rectilineal Pipes, etc.

$\frac{1728}{60''} = v$; $\frac{V^2 L}{(3.7\,d)^5\,83.1} = H$; $\frac{H\,(3.7\,d)^5\,83.1}{V^2} = L$; $\sqrt{\frac{H\,(3.7\,d)^5\,83.1}{L}} = V$;

$\frac{V^2 L}{83.1\,H} \div 3.7 = d$, and $\frac{a\,60''\,v\,\overline{P+H}}{12'' \times 33\,000} =$ IP. *V representing volume discharged* *cube feet per minute,* L *length of pipe in feet,* d *diameter of pipe in ins.,* H *head* P *pressure, both in lbs. and per sq inch,* v *velocity of discharge in feet per sec-, a area of discharge in sq. ins., and* IP *horse-power of friction of air alone.*

LUSTRATION.—Assume volume of air discharged 44000 cube feet per minute, neter of discharge pipe 40.5+ ins. (say 1280 sq. ins. net), length of pipe 1000 , and pressure at discharge 3.5 lbs. per sq. inch.

hen $\frac{44\,000 \times 1728}{1280 \times 60} = 990$ *feet*, and $(3.7 \times 40.5)^5 \times 83.3 = 6\,310\,406\,250\,000$.

$\frac{44\,000^2 \times 1000}{310\,406\,250\,000} = .3068-$ *lbs.*; $\sqrt{\frac{.3068 \times 6\,310\,406\,250\,000}{1000}} = 44\,000$ *cube feet;*

$\sqrt{\frac{1\,936\,000\,000 \times 1000}{83.1 \times .3068}} \div 3.7 = 40.5$ *ins.*, and $\frac{1280 \times 60 \times 990 \times \overline{3.5 + .3068}}{12 \times 33\,000} =$ 5 IP.

lume of Enclosed Air at 0° that may be Heated by One Square Foot of Iron Heating Surface.

Enclosure.	Heater in Cellar.	Heater in Room.	Enclosure.	Heater in Cellar	Heater in Room.
	Cub. ft.	Cub. ft.		Cub. ft.	Cub ft.
wellings	40	50	Large stores, average	90	110
fices	60	70	Hotels	100	125
ose stores	70	80	Churches	150	200

mmercial IP of Chimney for a Given Diam. of Flue.

Height of Chimney in Feet.

n. of ue.	50	60	70	80	90	100	110	125	135	150	175	200	225	250	300
s.	IP	IP	IP	IP	IP	IP	IP	IP	IP	IP	IP	IP	IP	IP	IP
5	16	18	19	[illegible]	—	—	—	—	—	—	—	—	—	—	—
0	84	92	100	107	113	119	124	—	—	—	—	—	—	—	—
5	—	—	250	270	288	305	321	345	353	385	—	—	—	—	—
5	—	—	—	330	370	405	438	465	490	530	560	—	—	—	—
5	—	—	—		860	900	935	1000	1036	1090	1185	1270	1345	1415	1480
0	—	—	—		—	1350	1410	1500	1556	1640	1770	1890	2000	2100	2190
0	—	—	—		—	1665	1725	1820	1880	1970	2115	2255	2390	2520	2645

r intermediate Diameters and Powers, take proportionate Diameters and Powers.
r Square Chimney deduct one-ninth to one twelfth of Diameter of Round, for Side

Friction of Water in Pipes. (*Weisbach.*)

$\frac{.1865\,l\,v^2}{d}\,C = h$. *l representing length of pipes in feet,* $v = \frac{183.34\,V}{d^2}$, *or velocity* *feet per second,* V *volume of water in cube feet elevated per second,* d *diameter* *es in ins.. and* C *a coefficient, ranging from .069 when velocity = .1 foot, .03* *oot, .0375 for 1 foot, .0265 for 2 feet, .023 for 4 feet, .0214 for 6 feet, .0205* *, .0193 for 12 feet, and .0182 for 20 feet.*

LUSTRATION.—Assume volume 125 cube feet, raised 25 feet per hour 2 ins. in diameter and 500 feet in length; how many feet of ver friction in the pipe be equal to?

Then $\frac{183.34 \times 125}{3600 \times 2} = 3.18$ velocity, and C = .028.

ence, $\frac{.1865 \times 500 \times 3.18^2}{2} \times .028 = 14.6$ feet, and $25 + 14.6 = 3$

Water Tube Boiler.

Proportions of Grate and Heating Surfaces of Water Tube Boilers, as Determined by an Extended Series of Experiments and Observations, with Different Fuels and at Different Localities. (1876 to 1884.)

(*Committee of U. S. Centennial Exhibition and Individuals.*)

Babcock and Wilcox Co.

Water evaporated from and at 212°.

Duration of Test.	Surfaces. Grate.	Heating.	Ratio.	Combustible consumed. Per Grate.	Per Heating Surface.	Coal per Grate per Hour.	Evaporation by Combustible.	by Coal.	Ash per cent.
Hours.	Sq. Ft.	Sq Feet.		Sq. Feet.	Sq. Feet.	Sq. Feet.	Lbs.	Lbs	
8	44.5	1676	37.7	8.88	.256	—	12.131	—	—*
120	50.7	1980	39.1	11.21	.26	12.99	11.62	9.71	13.7*
216	54.7	2148	39.1	12.22	.292	—	11.982	—	—*
24	61.9	2760	44.6	8.22	.198	—	11.626	10.09	13.2*
22	59.5	2757	46.3	14.25	.307	9.93	11.43	9.96	12.9*
13.5	39.7	1680	42.3	5.8	.137	6.26	12.495	11.53	7.5†¶
4	25	1403	56.1	12.41	.276	13.44	12.38	11.52	7 §
10.25	70	3126	44.7	18.15	.406	20	12.42	11.32	8.8*

Coals: * Anthracite, American. † Bituminous, Welsh. † Bituminous, Scotch. § Bituminous, Powelton. ¶ Test in London.

A Galloway boiler of standard efficiency, at this exposition, having a ratio of heating surface to grate of 25 to 1, and feed water at a temperature of 56°, gave the following results:

Consumption of coal, 8.87 lbs. per hour per sq. foot of grate. Pressure of steam, 70 lbs. per sq. inch. Water evaporated per hour per sq. foot of heating surface 3 lbs.; water evaporated per hour per sq. foot of heating surface in lbs. per lb. of combustible, 9.68 lbs., and per lb. of coal, 8.63 lbs.

Average Results of Thirty Tests at Different Locations and with Different Experts.

Coal consumed per hour per grate surface, 15.028 lbs. Water evaporated from and at 212° per hour per sq. foot of heating surface, 3.71 lbs.; water evaporated per hour per sq. foot of heating surface per lb. of combustible from and at a like temperature, 11.442 lbs.

Elements of a Comparative Test with a Return Fire Tubular Boiler. (*W. Barnet Le Van and J. C. Hoadley.*)

Water evaporated from and at 212° per lb. of combustible.—Water tubular, 11.255 lbs. Fire tubular, 10.571 lbs. Comparative economy by evaporation test, 6.47 *per cent.*

Combustible consumed per HP per hour.—Water tubular, 4.321 lbs. Fire tubular, 4.648 lbs. Comparative economy by engine operation, 7.57 *per cent.*

Lost heat in chimney. — Water tubular, 20.54 *per cent.* Fire tubular, 25.47 *per* Comparative economy, 7 *per cent.*

ing Arc Lights.—Combustible consumed: Water tubular, 4.6567 lbs. Fire 738. Comparative economy, 6.81 *per cent.*
l result was 7 per cent. in favor of the Water Tubular.

—Average evaporation from and at 212°: Combustible, 11.292 lbs.; From 100° and at 212°: Combustible, 10.96 lbs.; Coal, 10.67 lbs. of grate, 15.396 lbs. per hour.

ned by 20 tests and different coals, in excess of nominal rage moisture in steam 1.045 per cent.

coal with 12 per cent. of ash, 11.121 lbs. water evap- nd 9.252 of coal.

demanded in some manufacturing operations, most economical operation of triple and surfaces of these boilers are made of

To Compute Area of Cylinder of a Steam-engine . Grate and Heating Surfaces of a Boiler.

When Required Power is Given.—It is assumed that HP of a steam-engine tained by evaporation of 33.6 lbs. water per hour, at a temperature of 212° fron water at 100°.

NOTE.—This is a deduction from the elements of the estimate as given by the Am. Soc. of : Engineers, in order to put temperature of the feed at 100° instead of 212°.

Non-condensing (Single Cylinder). $\frac{V \times 33.6 \times HP}{60 \times 2\,R \times 2\,S\;12} \times 1728 =$ *area of cyl in sq. ins.* V *representing volume of* 1 *lb. water at terminal pressure of steam ir feet,* P *pressure of steam at termination of stroke of piston in lbs.,* R *number o olutions per minute, and* S *stroke of piston in feet.*

ILLUSTRATION.—Required HP of an engine is 300, initial pressure of steam i exceed 70 lbs. mercurial gauge, cut off at 5 stroke of piston of 4 feet, and nu of revolutions 60 per minute. What should be areas of cylinder of engine and and heating surfaces of boiler?

Steam at 70 lbs. pressure, clearance in cylinder and steam passages = 1.8 i 15 foot, point of cutting of = $4 \div .5 = 2$ *feet.*

Then (formula p. 711), $70 \times (\overline{2+15} \div \overline{4+.15}) = 36.26$ *lbs.* terminal pressure steam at this pressure has a density or volume, which is its reciprocal (foi p. 706) of 11.26 *cube feet* for each lb. of water contained.

Hence, $\frac{11.26 \times 33.6 \times 300}{60 \times 2 \times 60 \times 2 \times 4 \times 12} \times 1728 = 283.75$ *sq. ins.*, to which is to be for friction of engine and of load 10 per cent. = 312 *sq. ins.*

Inversely.—By ordinary formula area = 336 *sq. ins.*

Grate Surface.—Evaporation of fresh water in an efficient marine boiler, fi temperature of feed of 100°, is assumed, with a proportion of heating surfa grate of 30 to 1, to be, with a combustion of 20 lbs. coal per sq. foot of grat hour, 213 lbs. per sq. foot of grate, and 10.3 lbs. per lb. of coal.

Hence, $\frac{E\,HP}{L} =$ *area.* L *representing evaporation per sq. foot of grate per hc*

ILLUSTRATION.—Assume elements of preceding, with evaporation as above.

$$\frac{33.6 \times 300}{213} = 47.32 \text{ sq. feet.}$$

Heating Surface.—Then $47.32 \times 30 = 1419$ *sq. feet area.*

For the several types of boilers the following units should be used:

TYPE.	*Ratio of Heating Surface to Grate* 30 to 1 — Coal consumed per Sq. Foot of Grate per in Lbs.			50 to 1	
	15	20	30	15	20
Marine	164	214	314	183	242
Stationary	159	207	299	182	241
Portable	132	174	257	145	187
Locomotive	150	197	290	164	211
" Coke	131	170	247	159	197

Units of Heat in Fuels.

Anthracite	14 500	Petroleum, refined	
Bituminous	14 200	" crude	
Petroleum, light	22 600	Coal Gas	
" heavy	19 440	Water Gas	

To Resist Oxidation in Cast-iron

A coating of hot lime, which is much preferable to tar.

To Compute Relative Velocities of Steam Yachts, from Elements of their Construction, Capacity, and Operation.

RULE.—Multiply area of their grate surfaces by *Constant* due to the character of the combustion of their furnaces, divide product by cube root of square of their gross tonnage (U. S.), and cube root of quotient will give their relative velocities.

Or, $\sqrt[3]{\frac{G\,C}{T^{\frac{2}{3}}}} = V$. G *representing area of grate surface in sq. feet*, T *gross tonnage, and* C *a constant, viz. natural draught* 1. *Jet or exhaust* 1.25, *and blast* 1.6.

In the application of this rule, as alike to all others when there is material difference in the elements, as with large and small vessels, those that approach each other in general dimensions or capacities, as determined by certain ranges or limits of tonnage, should be classed together.

ILLUSTRATION.—The grate surface of a yacht is 27.5 sq. feet, her tonnage 71.24, and the combustion in her furnaces, jet.

$$\text{Hence, } \sqrt[3]{\frac{27.5 \times 1.25}{71.24^{\frac{2}{3}}}} = \sqrt[3]{\frac{34.75}{17.185}} = 1.26.$$

This result is an index of the capacity of the vessel, when compared with another in like manner.

Thus, assume one to be a fair exponent of her class, as from 40 to 60, 60 to 80, or 80 to 100, etc., tons, and her speed to be 12 knots per hour, or 60 minutes.

If then a competitor possessed the elements that by the above formula would give a result of 1.3, their relative capacities over a like course would be as 1.26 : 1.3 :: 60 : 61.9, and 61.9 − 60 = 1.9 *minute* = 1 *minute* 54 *seconds*, which is the time the yacht of greatest capacity would have to allow the other.

If the course was for a greater distance, as for 80 knots, than $\frac{80}{12} \times 1.9 = 12$ *min.* 4 *sec.* the allowance.

For Large Steamers.

$3.96\sqrt[3]{\frac{HP}{S^2}} = V$. S *representing area of immersed amidship section in sq. meters.*

NOTE.—A sq. meter is 10.764 sq. feet.

This formula is used in Europe, and is applicable only for vessels of great capacity and with a blast combustion.

Simple Water Tests.

For Hard or Soft Water.—Dissolve a small quantity of soap in alcohol. Put a ·rops of it in a vessel of water. If it becomes milky. it is hard, if not, it is soft.

Earthy Matters or Alkali.—Dip litmus paper in vinegar, and if on immersion the paper returns to its true shade, the water is free from earthy matter. Syrup added to a water containing earthy matter will turn it green.

...ic *Acid.*—Take equal parts of water and clear lime-water. If com... ...honic acid is present, a precipitate is produced, to which, if a few ...cid be added, an effervescence occurs.

...il the water to a twentieth part of its weight, drop a few grains ...f ammonia and a few drops of phosphate of soda into it, and ...t will precipitate to the bottom.

...ttle nutgall and mix it with the water; if it turns gray or ...—(2.) Dissolve a little prussiate of potash, and mix it ...esent, it will turn blue.

...f water put two drops of oxalic acid and blow upon it ...ent.

...us paper in it. If it turns red, it is acid. If ... is carbonic acid. If a blue paper is turned

TOBIN BRONZE. (*Hot rolled.*)

sonia Brass and Copper Co., New York, N. Y.,

Sole Manufacturer.

ɔific gravity 8.379. Weight of a cube inch .3021 of a lb. Tensile th 1-inch round rod 79600 lbs. per sq. inch. Elastic limit 54257 lbs. . inch.

ıgation in a rod 1 inch in diameter and 8 ins. in length 15.4 per Reduction 37.26 per cent.—*Fairbanks.*

ɔadily forged into bolts and nuts at a dark-red heat, Torsional strength ıastic limit equal to machinery steel.

Torsional Strength.

.5 inch in diameter and 1 inch in length, load at end of lever 1 foot.

sion 2.67°. Elastic limit 328 lbs. Rupture 633 lbs. Torsion point ure 92.2°.—*J. E. Denton.*

ɔhing Strength, maximum, 181000 lbs. per sq. inch.

Plates.

Weight per Square Foot.

ɔss.	Weight.	Thickness.	Weight.	Thickness.	Weight.	Thickness.	Weight.
	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
5	2.72	.4375	19.03	.8125	35.35	1.1875	51.66
	5.44	.5	21.75	.875	38.06	1.25	54.38
5	8.16	.5625	24.47	.9375	40.78	1.3125	57.1
	10.88	.625	27.19	1	43.5	1.375	59.82
5	13.59	.6875	29.91	1.0625	46.22	1.4375	62.53
	16.31	.75	32.63	1.125	48.94	1.5	65.25

Bolts and Rods.

Weight per Lineal Foot.

r.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diam.	Weight.
	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
	.177	.75	1.6	1.5	6.42	2.5	17.8	4	45.57
	.279	.8125	1.88	1.625	7.5	2.625	19.6	4.25	51.44
	.399	.875	2.18	1.75	8.7	2.75	21.53	4.5	57.64
	.544	.9375	2.5	1.875	10	2.875	23.52	4.75	64.24
	.711	1	2.84	2	11.38	3	25.53	5	71.16
	.899	1.125	3.6	2.125	12.87	3.25	30.05	5.25	78.46
	1.11	1.25	4.46	2.25	14.43	3.5	34.86	5.5	86.11
	1.34	1.375	5.36	2.375	16.06	3.75	40.01	6	102.4[illegible]

ɔ supplied in the form of Round, Square, and Hexagon bars; Plat , Wire, and Finished Piston Rods.

ng to its great strength and non-corrosive properties it is extensi in bolts, etc., for Marine and Naval machinery, Sugar-houses, ries, Pump rods and Pump linings, Condenser tube sheets, Yacht h shafting, etc.

p Forgings of every description.

ights of Steam-engines and Boilers wit

Per Indicated HP in Lbs.

ınt Steamer	480	Torpedo Boats	
Navy "	360	Marine Boilers	
oats	280	Locomotive "	

Weight and Strength of Ordinary Stud-Link Chain Cable.

Dimensions of Link. Diam.	Length.	Width.	Weight per Fathom.	Admiralty Proof-stress.*	Dimensions of Link. Diam.	Length.	Width.	Weight per Fathom.	Admiralty Proof-stress.
Ins.	Ins.	Ins.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Lbs.	Lbs.
.375	2.25	1.35	7.55	—	1.375	8.25	4.95	101.6	[illegible]
.4375	2.625	1.575	11.3	7 840	1.5	9	5.4	121	[illegible]
.5	3	1.8	13.4	10 080	1.625	9.75	5.85	142	[illegible]
.5625	3.375	2.025	17.2	12 320	1.75	10.5	6.3	164.6	[illegible]
.625	3.75	2.25	21	15 680	1.875	11.25	6.75	189	[illegible]
.6875	4.125	2.475	25.4	19 040	2	12	7.2	215	[illegible]
.75	4.5	2.7	30.2	22 680	2.125	12.75	7.65	242.8	[illegible]
.875	5.25	3.15	41.2	30 800	2.25	13.5	8.1	276.2	[illegible]
1	6	3.6	53.8	40 320	2.375	14.25	8.55	303.2	[illegible]
1.125	6.75	4.05	69	50 960	2.5	15	9	336	[illegible]
25	7.5	4.5	84	63 000	2.75	16.5	9.9	405.6	[illegible]

* Adopted by Lloyds.

NOTE 1.—*Safe Working-stress* is taken at half the Proof-stress.

2.—*Proof-stress* and *Safe Working-stress* for close-link chains are respectively two-thirds of those of stud-link chains.

3.—*Average Proof-stress* is 72 *per cent.* of ultimate strength, or 17 000 lbs. per sq. inch of section of both sides. Safe working-stress is half the proof-stress, or [illegible] lbs. per sq. inch of section.

Weight of close-link chain is about three times the weight of the bar from which it is made, for equal lengths.

4.—*Ultimate Strength* per sq. inch of section of metal is 35 000 lbs.

Comparing the weight, cost, and strength of the three materials, hemp, iron wire, and chain iron, the proportion between the cost of hemp rope, wire rope, and chain is as 2 : 1 : 3; and, therefore, for equal resistances, wire rope is only half the cost of hemp rope, and a third of the cost of chains. (Karl von Ott.)

Height and Retrocession of Niagara Falls. (*J. Pohlman.*)

1842.	Height.—American	167 feet.	} *Jas. Hall.*
	Horseshoe	158 "	
	Width.—American	600 "	
	Horseshoe	1800 "	
1875.	Receded.—American	60 "	} Lake Survey.
	Horseshoe	160 "	

1886.—Average retrocession 2.5 feet per annum (Woodward).

200 feet in 11 years, and 9 feet per year in 42 years.

Descent of the river below 15 feet per mile.

Bridge.—Over Oxus on Caspian sea, 6230 feet in length.

LENGTHS OF ENGLISH RACE-COURSES.

Course.	Miles.	Course.	Miles.	Course.
NEWMARKET.		DONCASTER.		GOODWOOD.
Across the Flat	1.292	Circular	1.925	Cup Course
Beacon	4.206	Fitzwilliam	1	LIVERPOOL.
Cambridgeshire	1.136	Red House	.711	New Course
Cesarewitch	2.266	St. Leger	1.825	NEW CASTLE
Round	3.579	Cup Course	2.634	OXFORD
Rowley Mile	1.009	EPSOM.		YORK.
Summer Course	2	Craven	1.25	Stakes Course
Two-year old, new	.700	Derby and Oaks	1.5	Two-mile
Yearling	.277	Metropolitan	2.25	

Railway Speed in England.

1885.—*North Western Railway.* To Crewe, 158.5 miles in 178 minutes without a stop.

Caledonian. Carlisle to Edinburgh, 100.75 miles, including 10 [illegible] miles of elevation of 1 in 80, in 104 minutes.

Loads per Sq. Foot from 100 Lbs. to 300 Lbs.

Span.	100 Lbs.			150 Lbs.			200 Lbs.			250 Lbs.			300 Lbs.		
	Depth and Weight per Yard.		Distance.	Depth and Weight per Yard.		Distance.	Depth and Weight per Yard.		Distance.	Depth and Weight per Yard.		Distance.	Depth and Weight per Yard.		Distance.
Feet.	Ins.	Lbs.	Feet.	Ins.	Lbs.	Feet.	Ins.	Lbs.	Feet.	Ins.	Lbs.	Feet.	Ins.	Lbs.	Feet.
8	4	30	4.6	4	30	3.1	5	30	3	6	40	3.9	6	40	3.2
	5	30	5.9	5	30	4	6	40	4.8	6	50	4.7	5	50	3.9
10	5	30	3.8	6	40	4.1	6	40	3	6	50	3	7	55	3.3
	5	40	4.8	6	50	5	6	50	3.7	7	55	4	8	65	4.4
12	6	40	4.2	6	50	3.4	7	55	3.4	8	65	3.6	8	65	3
	6	50	5.2	7	55	4.6	8	65	4.5	9	70	4.5	9	70	3.8
14	7	55	5	7	55	3.3	8	65	3.3	9	70	3.3	9	85	3.3
	8	65	6.7	8	65	4.5	9	70	4.1	10.5	90	5	10.5	90	4.2
16	8	65	5	8	65	3.3	9	85	3.7	10.5	90	3.8	10.5	105	3.6
	9	70	6.3	9	70	4.2	10.5	90	4.7	10.5	105	4.3	12.25	125	4.8
18	9	70	4.9	9	85	3.9	10.5	105	4.2	10.5	105	3.4	10.5	135	3.6
	9	85	5.9	10.5	90	4.9	12	96	4.6	12.25	125	4.5	12.25	125	3.7
20	10.5	90	6	10.5	105	4.5	10.5	105	3.4	12.25	125	3.6	12.25	125	3
	—	—	—	12.25	125	6	12.25	125	4.5	12.25	170	4.9	15	150	4.4
22	10.5	90	4.9	12	96	4	12.25	125	3.7	12.25	125	3	12.25	170	3.3
	10.5	105	5.6	12.25	125	4.9	15	125	4.5	15	125	3.6	15	150	3.6
24	12	96	5	12.25	125	4.1	12.25	125	3	12.25	170	3.3	15	150	3
	12.25	125	6.1	15	125	5	15	150	4.5	15	150	3.6	15	200	4.1
26	12.25	125	5.1	15	125	4.3	15	150	3.8	15	150	3	15	200	3.5
	—	—	—	15	150	5.1	15	200	5.2	15	200	4.2	20	200	4.7
28	15	125	5.5	15	150	4.3	15	200	4.4	15	200	3.5	20	200	3.9
	—	—	—	15	200	5.9	20	200	6	20	200	4.8	20	272	5.3
30	15	150	5.6	15	150	3.7	15	200	3.8	20	200	4.1	20	200	3.4
	—	—	—	15	200	5.1	20	200	5.2	20	272	5.5	20	272	4.6

Niagara River Power.

ıl through which the water is to be drawn commences at a dist above the Falls. The water-storage of the river is computed at les, viz., 87 620 of lake and 241 235 of shed. The annual rainfall b

ng the rainfall to be but 30 inches, the flow over the Falls would be per second. The Lake survey computes it at 265 000 cube feet.
' designed to be used by the company constructing the canal is 1200
and corrected determination of levels gives Lake Ontario 246 and Lal above mean tide at city of New York.

Height of Towers, Spires, etc.

(*Additional to page* 180.)

Tower, Paris	984.3 feet.	Cathedral, Strasburg..........	46
dral, Rouen	492 "	City Hall, Philadelphia........	53

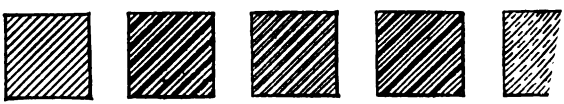
ıith and Meridian Distance and Altitude of at New York. C. H. (*Lat.* 40° 42′ 44″.)

e 21st, Zenith distance... 17° 15′ 44″	Dec. 21st, Zenith distance... 64°
Meridian altitude. 72° 44′ 16″	Meridian altitude . 25° 5

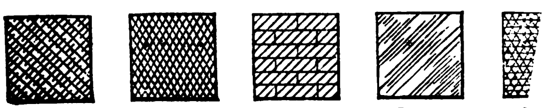
Water-pump.—First in use 283 years B.C. *Rotating* introduced i ntury. *Plunger pistons* invented by Morland (England), 1674. *Double acti* ı la Hire (France).

Symbolic Hatching and Designations.

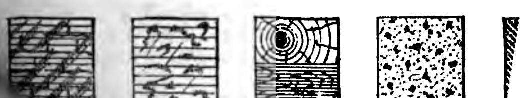
As adopted by Engineer Department, U. S. Navy.



CAST IRON. WROUGHT IRON. CAST STEEL. WROUGHT STEEL. BR



COPPER. LEAD. BRICK. GLASS.



TONE. EARTH. WOOD. LEATHER.

following are designed and added by th

NICKEL. GUM. ZINC.

sults of Experiments on Operation of Steam-Engine. (*C. E. Emery, M. E.*)

	Condensing.	Non-Condensing.		Condensing.	Non-Condensing.
der	16 × 42 ins.	18 × 42 ins.	Cut off	.189	.189
are	81.69 lbs.	73.37 lbs.	IP	78.79	115.43
mean effective.	31.06 "	29.47	Friction IP	10.09	13.07
utions per min.	60.3	73.6	Net IP	68.7	102.36

	Condensing.	Non-Condensing.
ter per net IP per hour in lbs.	29.231	25.39
l " " "	3.25	2.82
per IP per hour in lbs.	3.97	3.44
ative efficiency per steam	.988	1
" " " coal	.805	1

Safety Valves of Steam-Boilers.

lers operated at a low pressure of steam require proportionately larger safety s than when operated at a high pressure. Thus: If steam at 20 lbs. pressure 1. inch is raised to 30 lbs., a valve nearly one half more capacity is required; raised from 100 lbs. to 110 lbs., a valve of nearly one tenth more capacity is ·ed.

lting. Double belts will transmit one and one half times the power of

le belts are less effective per unit of area than narrow. Long belts are more ve than short. Driving belts may be driven at a velocity of 3500 feet per min. Lathe belts from 1500 to 2000 feet. Economy of wear requires less velocities.

Non-Conductors of Temperature.

Their Comparative Efficiency.

ials in Italics are wholly free from Carbonization or Ignition from slow contact with Boilers or Steam-pipes.

following Materials were used as Covering to a Steam-pipe 2 Ins. in Diameter.

ls of Water Heated 10° per Hour through One Square Foot of the Material. (*J. M. Ordway.*)

ial 1 Inch in Thickness.	Lbs.	Relative Solidity.	Material 1 Inch in Thickness.	Lbs.	Relative Solidity.
ool, loose	8.1	.56	13. *Anthracite coal powder*	35.7	5.06
athers of live geese	9.6	.5	14. Magnesia, calcined and compressed	42.6	2.85
mp black, loose	9.8	.56	15. Air alone	48	—
lt of hair	10.3	1.85	16. Asbestos, fine	49	.81
tton wool, carded	10.4	.2	17. Sand	62.1	5.27
mp black, compressed	10.6	3.44	18. Stag woo' threads of l		—
arcoal of cork	11.9	.53	19. Paper		
gnesia, calcined and loose	12.4	.23	20. Rice-ch		
gnesia, carbonate f, and light	13.7	.6	21. Bit. coal		
arcoal of white pine.	13.9	1.19	22. Asbesto		
gnesia, carbonate f, and compressed	15.4	1.5	23. Anth. co		
aster of Paris	30.9	3.68	24. Clay and		

ow of Several Rivers. Minimum

In Cube Feet per Minute.

wrence, at Brockville, Ont.	18 000 000.	Seine, at Par
ssippi, at St. Pauls, Minn.	2 000 000.	Mohawk, at C
cticut, at Holyoke, Mass.	300 000.	Thames, at L
at Pittsburgh, Penn.	100 000.	Chicago, at C
Illinois, at La Salle, Ill.	36 000.	

Standard U. S. Weights and Measures.

(*U. S. Coast Survey.*)

Lineal.

Inch to Millimetres.	Foot to Metre.	Yard to Metre.	Mile to Kilometres.	Metre to Inches.	Metre to Feet.	Metre to Yards.	Kilometre to Mile.
25.4	.304 801	.9144	1.609 35	39.37	3.280 83	1.093 611	.621 37

Chain = 20.1169 metres. Fathom = 1.829 metres. Sq. mile = 259 hectares. Knot = 1853.27 metres.

Square.

Inches to Centimetre.	Feet to Decimetre.	Yard to Metre.	Acre to Hectare.	Centimetre to Inch.	Metre to Feet.	Metre to Yards.	Hectare to Acres.
6.452	9.29	.836	.4047	.155	10.764	1.196	2.471

Volume. (*Fluid.*)

Dram to Millilitres.*	Ounce to Millilitres.	Quart to Litre.	Gallon to Litres.	Millilitre† to Dram.	Millilitre to Ounce	Litres to Quarts.	Decalitre to Gallons.	Hectolitre to Bushels.
3.7	29.57	.946 36	3.785 44	.27	.338	1.0567	2.6417	2.8375

Cube.

Inch to Centimetres.	Foot to Metre.	Yard to Metre.	Bushel to Hectoliter.	Centimetre to Inch.	Decimetre to Inches.	Metre to Feet.	Metre to Yards.
16.387	.028 32	.765	.352 42	.061	61.023	35.314	1.308

Weight.

Grain to Milligrams.	Av. Ounce to Grains.	Av. Pound to Kilogram.	Tr. Ounce to Grains.	Milligram to Grain.	Kilogram to Grains.	Hectogram‡ to Av. Ounces.	Kilogram to Pounds.
64.7989	28.3495	.453 59	31.103 48	.015 43	15 432.36	3.5274	2.2046

Quintal to Av. Pounds, 220.46. Tonnes § to Av. Pounds, 2204.6. Grams to Tr. Ounce, .032 15. Av. Pound = 453.592 427 7 grams. Kilogram = 15 432.356 39 grains.

NOTE.—The U. S. yard is equal to the British yard. British gallon = 4.5434 litres. Bushel = 36.3477 litres.

Value of the Metre in terms of the British Imperial Yard, and of the Committee Metre (C.M.) of the U. S. Coast and Geodetic Survey. (*O. H. Tittmann.*)

Authority.		Value.
Hassler	39.380 917	39.369 94
Kater	.370 79	39.3699
[illegible]	.369 678	39.369 73
[illegible]	.370 432	39.3697
[illegible]	.369 85	39.369 84
	Mean....	39.3698

[illegible] and Valley of the Jordan. Portions of these are [illegible] level of the sea. (*R. E. Peary.*)

[illegible] 1501 to 1889 the ratio of gold and silver varied

[illegible] Wood columns or posts, set in earth opposite [illegible] durable than when set with it.

[illegible] ‡ 100 Grams. § Milliers.

Miscellaneous Operations.

move Paint. Apply chloroform.

store Color of a Fabric. When destroyed by an acid, ap-
a to neutralize it, and then chloroform.

vare. Warm, and cover with a mild solution of collodion in alcohol,
vith a soft brush.

rames. To restore, rub with a sponge moistened with spirits of

ain. On silver, rub with salt.

ust. To remove from white fabrics, saturate the spots with lemon-
lt, and expose to the sun.

ains. Wash with pure fresh water, and apply oxalic acid. If this
stain to a red color, apply ammonia.

rs on Brick. Apply oyster-shells on the top of a clear fire.

Antidotes for Poisons.

Additional to page 185.

d Wine or *Tartar Emetic.*—Warm water to induce vomiting.

r *Fowler's Solution.*—Emetic of mustard and salt, a tablespoonful.
, sweet-oil, or milk.

-Oil of vitriol, corrosive sublimate, sugar of lead.

da or *Potash*, and *Volatile Alkali.*—Drink freely of lemon-juice or
ater.

cid.—Flour and water, and glutinous drinks.

of Soda, *Copperas*, or *Cobalt.*—Administer emetic; soap or mucilagi-

n.—Apply cold water to head and face, artificial respiration, and gal-
v.

, Morphine, or *Opium.*—Administer strong coffee, mustard flour, butter
rm water, and exercise.

or *Oxalic Acid.*—Give magnesia mixed, and soap dissolved with fresh

Silver.—Salt in water.

f Zinc or *Red Precipitate.*—Give milk or white of eggs copiously.

Acid.—Aqua fortis.

.—Emetic of mustard or sulphate of zinc, aided by warm water.

Motive Power of the World.

Steam-engines. *In Horse-Power.*

s....	7 500 000	Germany........	4 500 000	Austria	1 500 000
.....	7 000 000	France..........	3 000 000	Other countries.	19 000 000

Steam-boilers in Foreign Countries.

uding Locomotive.. 51 390 | Germany .... 60 700 | Austria 120

Locomotives in Foreign Countries.

7000 | Germany... 10 000 | Austria.... 2800 | Other

-engines of the world represent the power or work

(*Bureau of Stat*

estructive Stress of Belting. (*Ho*

In Lbs. per Sq. Inch.

	Maximum.	Minimum.	Extension.*	Material.	Max mum.
	Lbs.	Lbs.	Inch.		Lbs.
r.	8000	2850	.018	Rubber	388
.	6750	3000	.18	Cotton belt'g	291

* At 400 lbs. per sq. inch.

Largest Constructions and Natural Formations.

New Opera-House, Paris.—Covers 3 acres, and has a volume of 4 287 000 feet.

Popocatapetl, Highest active *Volcano*, Mexico.—Has a crater one mile in diameter and 1000 feet in depth. (See p. 182.)

Telegraph Wire over river Kistnah, India.—6000 feet in length and 1000 feet in elevation. (See p. 179.)

Chinese Wall, Built 220 B.C. (See p. 179.)

Lambert Coal Mine, Belgium.—3490 feet in depth.

Mammoth Cave, Kentucky.—Some of its chambers are traversed by navigable branches of the subterranean river Echo.

St. Gothard Tunnel.—Its summit is 900 feet below the surface at Andermatt, and 6600 feet below the peak of Kastlehorn. (See p. 179.)

Bibliothèque Nationale, Paris.—Founded by Louis XIV., contains 1 400 000 volumes, 300 000 pamphlets, 175 000 MSS., 300 000 maps and charts, and 150 000 coins and medals. Engravings 1 300 000, contained in 1000 volumes, and 100 000 portraits.

Desert of Sahara, Africa.—Length 3000 miles, average breadth 900 miles, area 2 000 000 sq. miles.

Pyramid of Cheops, Egypt.—Volume of masonry 89 028 000 cube feet; weight of stone computed at 6 316 000 tons. (See p. 174.)

Bell, Moscow.—Circumference at base 68 feet, height 21 feet. (See p. [illegible])

Bridges.* *Rialto*, Venice.—A single arch of marble, 98.5 feet in length.

Clifton Suspension, Bristol, Eng.—Span 703 feet, elevation 245 feet.

Niagara Suspension, U. S.—Cantilevers, of steel, length 810 feet. Elevation above the rapids 245 feet.

Britannia, England.—1512 feet in length, and elevation 103 feet.

Forth, Frith of Forth, Scotland.—Length 8098.5 feet, exclusive of approaches [illegible] feet. Two Cantilever spans of 1710 feet each. Piers 360 feet above water. Roadway 150 feet in the clear above water. Iron and steel 54 000 tons. [illegible] tons.

Tay, Scotland.—Length 2 miles, 85 piers, and elevation [illegible] feet.

Columns or Pillars.

When a column or pillar is without its vertical line, one with slightly rounded ends becomes capable of greater resistance than one with square ends.

Experiments at the U. S. Arsenal at Watertown, Mass., developed that the [illegible] resistance of timber, to transverse compression or crushing, was about one-third of its resistance to longitudinal compression, and hence, that the area of [illegible] or the head of a timber column, should proportionately exceed that of the [illegible]

Steam-engine Notes.

Horse-power,† *Nominal*.—Is usually computed from the volume of [illegible] charged from the cylinder. Its measure for an ordinary non-condensing [illegible] about [illegible] of its actual power. It refers more to the dimensions of an engine than its capacity.

Indicated.—Is the measure of the force exerted by an engine, and from [illegible] be deducted for leaks, friction of its parts, and of its connecting parts [illegible]

Feed Water.—Ordinarily 2 to 3.5 gallons or 17 to 30 lbs. of water are required for each IHP.

Fuel.—The ordinary consumption of fuel may be taken at 5 lbs. per IHP [illegible] non-condensing engine, and 2 lbs. for a condensing.

Boilers.—12 to 15 sq. feet of heating surface, or [illegible] to [illegible] of grate surface [illegible] natural draught, will give one IHP.

Flow of Steam.—The velocity of it in feet per second may be determined [illegible] formula, [illegible] Thus for a pressure of 100 lbs. per sq. [illegible] velocity of [illegible] feet may be obtained. [illegible]

* [illegible] † [illegible]

antic and Pacific Oceans. There is not any difference in the
ıvels of these Oceans at Aspinwall and Panama, as determined by Geo. M.
who constructed the Panama Railroad.

Origin and Period of Great Inventions.

See also Chronology, pp. 71, 72, 915.

ngine.—Amonton, 1699. Stirling, 1827. Ericsson, 1855.
ump.—Otto Gueriche, 1650. *Anemometer.*—Walfius, 1709.
on.—First, Lyons, France, 1783. *Barometer.**—Torricella, 1643.
ry.—Electric, 1745; claimed by Kleist, Cunæus, and Muschenbroch.
es (Suspension).—Of chains, China, 100 B. C.
nets.—At Bayonne, 1670. Socket bayonet, 1699.
—In Christian church, 400; in France, 550. *Bellows.*—Egypt, 1490 B.C.
mer Steel.—Sir Henry Bessemer, 1856. *Blankets.**—England, 1340.
ing.—Germany, 1620. *Bullets.*—Of stone, 1418; of iron, 1550.
Printing.—Egypt; introduced in England 1696.
ra Obscura.—Roger Bacon, 1214; Newton, 1700; Daguerre, 1839.
les.—Of tallow, 1290. *Cannon.*—1118; England, 1521.
iages.—Vienna, 1515; England, 1580.
*s.**—To strike, by Arabians, 800; by Italians, 1200.
*—1184 B.C.; China, 1200 B.C.; Rome, 576; England, 1101.
*ıass.**—China, 2634 B.C. *Cotton Gin.*—Whitney, 1793.
ng.—1490 B.C. Prussian Blue, Berlin, 1710.
ımite.—Sobrero, 1846; Nobel, 1867.
*ric Discoveries.**—Leyden Jar, Cunæus, 1746; Electric Light, Davy, 1800;
tent of it, Greene & Staite, 1846.
ro-Magnetism.—Oersted, Copenhagen, 1819.
rotyping.—Jacobi of Russia and Spencer of England, 1837.
aving.—China, 1000 B.C.; on metal, 1423; line or steel, 1450; etching, 1512.
-Murdock Cornwall, 1792; Meter, Clegg, 1807; Dry-meter, Malam, 1820.
.*—Egypt, 1740 B.C. Windows, France, 12th century.
Leaf.—Egypt, 1700 B.C. *Gunpowder.*—Unknown; rediscovered 1324.
shoes.—300; of iron, 480.
aulic Press.—Bramah, 1796. *Hydraulic Ram.*—Whitehurst, 1772.
ogen.—Isolated by Cavendish, 1766. *Iron Vessels.*—J. Wilkinson, England,
hip, 1821; Steam-boat, 1830; Ship building, 1833.
idoscope.—Sir Daniel Brewster, 1814–17. *Knives.*—Table, England, 1550.
boat.—1817. *Lithography.*—Senefelder, about 1796.
notive.—Watt, 1769 and 1784. Cugnot, 1769.
hes.—Friction, 1829. *Medicine.*—From Greece, in Rome 200 B. C.
rs.—Glass, Venice, 13th century. *Newspaper.*—First authentic, 1494.
ibus.—Paris, 1827.
ns.—755. England, 951. *Oxygen.*—Priestley, 1774.
r.—From silk, China, 120 B.C.; from rags, Egypt, 1085.
s.—Of steel, 1803; gold, 1825. *Pencils.*—Of lead, 50. Eng
forte.—Italy, 1710. *Phonograph.*—Edison, 1877.
graph.—England, 1802; perfected, 1841. *Pottery.*—Old
Office.—Vienna and Brussels, 1516. *Stamps.*—England
*ting.**—Types, L. Coster, 1423.
*road.**—Passenger, England, Sept. 27, 1825.
ing-machine.—Patented, England, 1755.
r.—1858; Pullman, 1864. *Soap.*—England, 16th c
—Italy, 15th century.
—A. G. Bell and C. J. Blake, Boston, 1874.
to D. Bushnell, 1777.

** Indicates that the subject is also given at pp.* 71, 72.

Values of some Precious Metals.

Per Pound Troy.

Cobalt	$ 10	Osmium	$ 590	Rhodium	$415
Gold	250	Platinum	102	Ruthenium	975
Iridium	295	Potassium	25	Silver *	11

* Variable.

Expenditure in England for Various Purposes and of Articles Compared with that of Spirituous Liquors.

In Millions of Pound Sterling.

Missions	1	Tea, Coffee, etc.	20	Woollen Goods	[illegible]
Education	11	Sugar	25	Bread	[illegible]
Fuel for Households	15	Milk	30	Rents	[illegible]
Linen and Cotton	20	Butter and Cheese	35	Liquors	[illegible]

Aluminum.

Elastic limit of bars in tension 14 000 lbs. per sq. inch. Specific heat .2185. [illegible] at 1400°. Malleable at from 200° to 300°.

Tensile strength, ultimate, 26 000 lbs. Modulus of elasticity, 12 000 000.

Shrinkage .022 per linear foot. It is comparatively unaffected by exposure to [illegible] or water. Specific Gravity .0926. A cube foot weighs 160.013 lbs.

Linear expansion 32° to 212° .0000206.

(*Continued on page* 976.)

Bushels of Seed Required Per Acre.

In Bushels per Acre.

Barley	1.5	to 2.5	Flax	.5	to 2	Oats	2	to 4
Beans	1	" 2	Grass, blue	.625	" .875	Parsnips	.5	" [illegible]
Buckwheat	.75	" 1.5	" orchard	1.5	" 2.25	Pease	2.5	" 3[illegible]
Carrots	.75	" 1.5	" Herds'	.375	" .5	Potatoes	5	" 10
Clover, red	.16	" .33	" Timothy	.5	" 1	Rice	2	" 2.5
" white	.16	" .33	Hemp	1	" 1.5	Rye	1	" 2
Corn, brown	1	" 1.5	Millet	1	" 1.5	Turnips	.06	" [illegible]
" Indian	.25	" 1	Mustard	.25	" .625	Wheat	1.5	" 2

See also page 193.

Domestic Remedials.

[illegible]—Discharged by an acid, can be restored by Ammonia.

—Carbolic Acid (20 drops), evaporated on a hot surface, as a shovel, [illegible] from a room.

remove stains from a white fabric, wet with Milk and cover with Salt.

[illegible]—May be discharged by Buttermilk.

Camphor Gum, vaporized over the chimney of a gas-burner or lamp [illegible] from a room.

re them off, apply Chloride of Lime to their locality.

he noxious effects removed by Chloride of Lime.

Remove patient to a cool place, administer water freely, [illegible] Soda.

[illegible]ve Values of Food for Sheep.

Wool and Tallow Produced.

Wool.	Tallow.	Food.		Wool.	Tallow.
Lbs.	Lbs.			Lbs.	Lbs.
.97	.99	Corn-meal, wet	.83	.93	.89
.7	.7	Buckwheat	.79	.7	.55
.78	1	Rye, without salt	.58	.91	.7
1	.7	Potatoes, with salt	.3	.45	[illegible]
.97	.58	" without salt	.28	.45	[illegible]

Croton Aqueduct. *New York*, 1890.

Dimensions, Length, and Capacity.

Tunnel proper........................ 29.63 miles } 30.75 miles in length.
Aqueduct in open trench.............. 1.12 "

Pipes to Central Park reservoir, 2.37 miles in length.

Tunnel under Harlem river, 307 feet below tide-water level.

ourse.—From Croton Lake, 350 feet above the Dam, and runs generally Southerly, ough Westchester Co. and the 24th Ward of New York, to a point 7000 feet N. of ome Park, with a uniform inclination of .7 feet per mile; its general form, that a horse-shoe with curved invert; being 13.33 feet in height and 13.6 feet in dth; having a computed capacity of 318 millions of gallons per day. From ence, where it is contemplated to construct a large reservoir, for the supply of e annexed districts of the city, to its termination at 135th Street and 10th Avenue, capacity is reduced to 250 millions of gallons per day, and the Aqueduct which om there is to be operated under pressure, is circular in its section, 12.3 feet in ameter, with varying inclinations, the portion under the Harlem river being .5 feet.

From 135th Street it is connected to 12 cast-iron pipes, 48 ins. in diameter, 4 of ich connect with the old Aqueduct, 4 with the present City distribution, and 4 ding through Convent, (9th) and 8th Avenues to the Reservoir in Central Park. e operating capacity of all being equal to that of the Aqueduct, 250 millions of lons.

he Aqueduct is for the greater portion of its length a tunnel, it raising to the face but at four points, from which it can be emptied through gates into the acent rivers.

apacity.—The water-shed of the Croton, in extreme dry weather, with storage, 50 million gallons per day.

he present storage system includes Croton Lake, Reservoir at Boyd's Corners, middle branch Reservoir of the Croton valley, and several lakes, with a total acity of 10000 million gallons: three dams being in progress of construction and ers contemplated, viz., one at Carmel and one at Quaker Bridge.

he Capacity of the Reservoir in Central Park is computed at 1000 million gallons.

Ice.

Additional to p. 195.

.5 ins. thick will support a man; 5 ins., an 84-lbs. cannon; 10 ins., a body of en; 18 ins., a railroad train.

Yield of Oil in Seeds.

Per Cent.

ape	55	Mustard, white	37	Oats	6.5
lmond, sweet	47	Hemp	19	Clover-hay	5
" bitter	37	Linseed	17	Flour-wheat	3
urnip	45	Corn, Indian	7	Barley	2.5

Additional to page 189.

Historical Events and N Facts.

Australia.—Discovered 1622.

Banana.—Produce per acre 44 times greater imes gr han wheat.

Camels.—Some can travel 800 miles in 8 days

Catacombs.—Of Rome, remains of 6000000 bo

—Authentic history of it, 3000 B.C. C

ry of Alexandria—47 B. C. contained 400

—Steel, consumption 4000000 per day.

ry.—Abolished in Eng. West Indies, 1834;

le reached by Explorer

The distance from this to the

Influence of the Rotation of the Earth on Moving Bodies.

The Rotation of the Earth on its axis effects an appreciable displacement of the rails in a line of railroad.

In the case of an express train weighing 400 tons, running N. at the rate of 50 miles per hour, the pressure on the right hand or Eastern rail is computed at 500 lbs., and with a steamer, alike to the Inman Line "City of New York," the pressure is computed at 936 lbs. This lateral force increases to the Poles. (*T. Von Baris.*)

Bacteria in Earth-soil.

In Virgin soil; soil from beneath Roadways; from Gardens; adjacent to Factories; from Courtyards and Cemeteries.

Depth below Surface.	Germs per Cube Centi-meter.*	Depth below Surface.	Germs per Cube Centi-meter.*	Depth below Surface.	Germs per Cube Centi-meter.*	Depth below Surface.	Germs per Cube Centi-meter.*
Meters.	No.	Meters.	No.	Meters.	No.	Metres.	No.
1	124 800	2	750	1	64 200	2	590

* .061 022 cube inches.

The number very rapidly decreases in the deeper layers of the earth, both in virgin soil and in that which has been polluted. (*John Reimers.*)

Water-meters.

Worthington's. New York.

Diam. of Receiving Pipe.	Volume delivered per Minute.		Diam. of Receiving Pipe.	Volume delivered per Minute.		Diam. of Receiving Pipe.	Volume delivered per Minute.		Diam. of Receiving Pipe.	Volume delivered per Minute.	
Ins.	Cube ft.	Galls.	Ins.	Cube ft.	Galls.	Ins.	Cube ft.	Galls.	Ins.	Cube ft.	Galls.
.625	1.5	11.25	1	5	37.5	2	8	60	4	60	45[illegible]
.75	3	22.5	1.5	6	45	3	18	130	6	120	9[illegible]

NOTE 1.—The volume of delivery here given, for each meter, can be exceeded.

2.—Extreme velocity of a meter produces incessant and improper resistance; hence, in order that the instrument may operate only within a perceptible reduction of the head of the supply, it should be of a capacity to effect its duty at a moderate velocity of operation.

Telescopes.

Galileo's first telescope magnified but three times; but by the addition of a concave eye and convex object glass he attained a magnifying power of 30 times.

The construction of large lenses is at present limited by the chromatic aberration or separation of light in a telescope.

Euler was the first to discover the principle governing this aberration and the method of abolishing it.

[illegible]iameters of the Principal Objective Glasses.

United States.

[illegible]tion.	Diameter.	Focal Length.	Location.	Diameter.	Focal Length.
	Ins.	Feet.		Ins.	Feet.
[illegible]	[illegible]2	—	Rochester...........	16	22
[illegible]	[illegible]	—	Washington.........	26	32.47[illegible]
[illegible]	[illegible]2.5	15	University, Va.......	26	25
[illegible]	[illegible]2.56	20.2	Lick Observatory....	36	56.2

[illegible]fornia contemplates the construction of one of 40 in[illegible]

[illegible] the U. S. are, Gates Head, England, 24 ins.; Vienna [illegible] ins.; Pulkowa, Russia, 30 ins.

[illegible] four lenses of 24 inches.

Manufacture of Ice.

Machinery and Apparatus.

c- f 24 s.	Steam-Engine.		Compressors.	Blocks of Ice.	Water required per Minute.	Coal.	Operators.			Weight of Engine and Plant.
							Engineers.	Firemen.	Laborers.	
	Ins.	Rev.	Ins.	Ins.	Gallons.	T's.*				Lbs.
	7×9	90	5×10†	8×8×28	5	.5	2	2	—	20 000
	8×16	80	5×15	8×15×28	15	1	2	2	2	58 000
	10×20	75	6×18	8×15×28	20	1.5	2	2	2	69 000
	12×30	70	8×20	11×22×28 / 11×11×28	30	2	2	2	3	101 000
	14×30	65	8×25	11×22×28 / 11×11×28	35	2.5	2	2	3	129 000
	14×30	65	10×20	11×22×28 / 11×11×28	40	3	2	2	4	167 000
	16×30	55	10×30	11×22×28 / 11×11×28	50	4	2	2	5	190 000
	—	—	—	11×22×28 / 11×11×28	60	5	2	2	6	225 000
	18×36	50	12×30	11×11×28	90	6.5	2	2	7	260 000
	20×36	50	15×30	11×11×28	—	—	2	2	8	—
	24×36	45	12×30‡	11×11×28	—	—	2	2	9	—
	26×48	45	20×36	11×22×28	100	13	2	2	10	360 000

* 2000 lbs. † One compressor. ‡ And one 16×36 ins. additional.

others two compressors, and all single acting.

ssure of Steam.—For all 75 lbs. per square inch.

-off. —For the three first, which are slide valves, three eighths. For the s, as Corliss engines, one fifth.

e volumes of ice above given cover that lost in thawing the molds to release it. coal given as that required is inclusive of that required to distil water from h to make the ice.

TE.—In order that the proper dimensions of engine and plant may be arrived r a required volume of ice, it is necessary that the quantity and temperature e water supply should be furnished.

—The ice is produced from water of distillation; hence, it is clear and trans- nt.

When a Machine is operated by Water-power. As the r from which the ice is made is not distilled from steam, as in the case where m is the motive power, the ice produced is less clear or transparent, and is wn as "white ice."

Refrigerating.

ngines for Refrigerating are in all respects alike to ... aking, with thirds more capacity. As distilled water is not r... ng of fuel in consequence is fully thirty per cent. F... lves a much less expenditure of water than when ...

ements of a Test of Operation a... Refrigerating Machi...

Ice Liquefied in 24 *Consecutive Hours*, 78.41 ...

Steam-engine.—Non-condensing, 18×36 *ins. Compress...*

Pressure of Steam, 86 *lbs. Revolutions per minute*, 56.5

IP—*Steam-cylinder*, 84.3. *Of compressors*, 67.78.

Temperature of condensing water, 76.2°. *Of condenser ro...*

Volume of condensing water per minute, 21.19 *gallons. Of ... fed* = 2 496 900 *lbs.*

Evaporating pressure, 25.22 *lbs. Condensing pressure*, 157.1...

Anthracite coal, consumed, 6108 *lbs. Combustible*, 83.63 per ...

Coal per IP per hour, 3.02 *lbs. Consumption equivalent to ... of ice*, 77.88 *lbs.*

Asphalt and Asphalt Pavement.

Barber Asphalt Paving Co., New York.

Asphalt rock is an amorphous limestone, impregnated with about 10 per c bitumen. Trinidad Asphalt is a mixture of sand, pulverized limestone, and bi forming an artificial impregnated sandstone.

In the cities of Europe, where asphalt pavement has been laid, the practi spread from 1.5 to 2.5 inches of it on a bed of concrete 6 ins. in depth.

The process of preparing the material for use is to crush the rock to powd it to about 280°, spread it on the concrete, and then compress it by ramme

The use of natural bitumen, found in the United States, as the Albert Grahamite, was resorted to, but without success, when the pitch or asphalt Trinidad, W. I., was discovered; by combining this material with highly ref troleum, a satisfactory cement was produced, which being mixed with a sh cious sand and powdered limestone, a desired sandstone was formed; a co possessing the necessary firmness and resistance to the changes of temperat durability, under the wear of loaded vehicles, combined with smoothness, ness, and comparative freedom from noise; without the facility for the slip horses' feet, usual with pavements with smooth surface. So evident was ful application of this construction, that in 1870 an essay of its merits was Newark and New York, and in 1876 it was further essayed on an extended Washington, its merits being evidenced by a Board of U. S. Engineers. Sinc time it has been laid in over 60 other cities in the U. S. to an extent 12 000 000 square yards.

The advantages of such a pavement are the reduction of the resistance to t economy of transportation, and freedom from jolting in travel, added to cle and public health, as it is without seams or joints wherein filth may be col

Its durability in wear is less than granite trap, and greater than sandston or macadam.

As regards the cost of its maintenance, it is less than that of any other maintained in like condition of repair

Origin and Development.

The utility of asphalt for covering of a road was not discovered until 18 phalt rock, broken up, was laid in the manner of a macadamized road, and sult was such, that in 1854 a street in Paris was laid with compressed asph foundation bed of concrete.

In 1869 it was first laid in London, and is now extensively laid in the c Europe to an extent in excess of 1 500 000 square yards.

Substitutes. — *Tar.* As a substitute for it it was essayed to use t pensive tar, obtained from gas-works; but as it is deficient in the required ing qualities, susceptible of being rendered viscid by the heat of summer, an by the cold of winter, the use of it was abandoned.

Wood.—Wood-pavement is laid in London and Paris on a foundation of c and it lasts from 4 to 6 years.

Stone-blocks filled in with bitumen water-proof filling has been practised w cess. In some of the principal cities of Europe, the uniformity in the dim shape of the blocks contribute to their durability. The cost of such a pa xcess of all others.

...dam.—Macadam pavement is unsuited for cities from the wear o and the great cost of maintenance.

—Brick, hard bu... d in two courses on 6 inches of sand, t ... its face, and ... its longitudinal edge, has been used in I ... Illinois. ... such a pavement depends wholly on t ... of the ... rning. In general practice it was fou ... durin...

...llm... in his report (1879) submits the following:

—A good pavement must be smooth, and to p ... a safe foothold for animals, and not polish or ... as nearly as possible, noiseless and free fro ... terial, laid upon a firm foundation, and be ... all seasons of the year.

Suitable Foundations for Pavements.

ı and unyielding foundation is quite as necessary for stability and endurance ement as for any other structure.

ring are suitable foundations for street-pavements, in order of value, pro- ıeir thickness is adapted to character of subsoil and nature of traffic, viz.: ulic concrete 5 to 8 ins. in thickness; 2. rubble-stone set on edge side by side, in close contact, with interstices filled in with hydraulic concrete; 3. an old pavement properly brought to slope and grade; 4. rubble-stone set on edge ged closely in contact like sub-pavement of a Telford road; 5. an old pave- stone-blocks, cobble, or rubble stone; and 6. an old Macadamized or gravel a compost layer of broken stone or gravel, 8 or 10 inches thick.

est pavements now prominently before the public, classified with respect to erials of which they are made, are Asphalt, Stone block, Wooden block, and pavements. The wooden-block pavement is not entitled to a place in the

Pavements.—The best is formed with rectangular blocks from 3.5 to 4.5 ins. o to 13 in length on wearing surface, and 8 to 9 inches deep, set upon their edge across the street, upon a foundation of hydraulic concrete.

Pavements.—Best asphalt is one having for a foundation a bed of hy- cement, or something equivalent thereto in firmness and durability, and for ing surface either the natural bituminous limestone known as asphalt rock, from the Jurassic region on the confines of Switzerland, or, preferable thereto, ially compounded mixture of refined asphaltum and silico-calcareous sand, the calcareous ingredient is finely pulverized limestone. As the material named pavement comes principally from vicinity of Neufchatel, the pave- known as the Neufchatel. Asphaltum for the other pavements referred to from Island of Trinidad, and the pavement is sometimes called the Trinidad

atel pavement.—Has been extensively laid in London, Paris, and other Eu- cities.

ugh these two pavements represent the best type of street surface, there is teristic and somewhat important difference between them, due to the fact Trinidad contains nearly 75 per cent. of sharp silicious sand, and does efore, become polished and slippery by wear; while the Neufchatel, being ed entirely of bituminous limestone (a species of amorphous pulverulent without grit, impregnated with bitumen), is by no means free from this fault. y of asphalt pavement adapted to streets of exceptionally steep grade, is one with rectangular blocks of compressed asphalt concrete.

mparative Merits of the Several Pavements.

First Cost.—In cost of construction, wood is the cheapest; Coal-tar com- econd; Sheet asphalt like the Trinidad third; Stone-blocks fourth, and locks fifth.

Durability.—Assuming each of the four pavements named to be the bes. stone and asphalt will possess the longest life, and wood and coal-tar the shortest. Between the first two and the last two ther ...n. stone be of good quality, asphalt will take first place an

of Maintenance.—Order of merit under this head wou' first, and wood and coal-tar last. If the asphalt is goo stone must be both tough and hard in order to maintain

elative Resistance of Roadways to T

At Low Speed. (*Rudolph Herring, C. E.*)

...dway.	Resistance in Terms of the Load.	Authority.	Roadway.	Resist. in Ter of the Lo
...ay...	.005	*Gordon.*	Plank	.025
.....	.00[illegible]	*do.*	Stone-block....	.04
.....	[illegible]	*Morin.*	Gravel.........	.04
...		*Kopack.*	Cob. stone, good	.033
...		*MacNiel.*	Earth	.125

Sub-Marine Torpedoes.

Formula for Determination of Pressure per Square Inch of Various Explosives at Different Distances.

$\sqrt[3]{\left(\frac{6636\,(\Delta + E)\,C}{(D + .01)^{2.1}}\right)^2} = P.$ Δ *representing angle with the vertical passing through the centre of the charge, made by a line drawn from it to the surface exposed to the shock, determined from the nadir,* in degrees;* E *a constant for the explosive, as determined by experiment;* C *weight of the explosive in lbs.;* D *distance from centre of the explosive to the surface exposed, in feet; and* P *the mean pressure, corresponding to that which would be transmitted to a disc of copper, by a Rodman indenting-tool, per square inch of surface exposed to the shock, in lbs.* (*Brev. Brig. General H. L. Abbott, U. S. A.*, 1881.)

Value of E, *or Relative Strength of Explosives Fired under Water.*

Explosive.	Nitro-glycerine.	E	Downward $\Delta = 0°$.	Horizontally $\Delta = 90°$.	Upward $\Delta = 180°$.	Explosive.	Nitro-glycerine.	E	Downward $\Delta = 0°$.	Horizontally $\Delta = 90°$.	Upward $\Delta = 180°$.
Dualin..........	—	232	116	111	108	Forcite No. 1..	—	333	—	—	—
Dynamite No. 1 †	75	186	100	100	100	Tonite.........	—	118	—	—	—
" No. 2.	36	120	75	83	88	Rackarock.....	—	220	—	—	—
Explosive Gelat.	89	259	125	117	113	Nitro-glyc'ne..	100	111	71	81	[illegible]
Gun-cotton	—	135	81	87	91	Rendrock.....	20	101	67	78	[illegible]
Electric No. 1...	33	67	51	69	77	"	40	160	91	94	[illegible]
" No. 2...	28	43	38	62	72	"	60	166	93	95	[illegible]
Hercules No. 1..	77	211	109	106	105	Vulcan No. 1..	30	99	66	78	[illegible]
" No. 2..	42	118	74	83	87	" No. 2..	35	114	72	82	[illegible]

ILLUSTRATION.—Assume the distance between the line of the centre of a charge of dynamite No. 1 and the bottom of a vessel to be 5 feet, the angle between the line of centre of the distance and the bottom, measured from the nadir, to be 180°, the constant for the charge 186, and its weight 100 lbs. What would be the mean pressure on the object in lbs. per sq. inch?

$$\Delta = 180°, \quad E = 186, \quad C = 100, \text{ and } D = 5.$$

$$\sqrt[3]{\left(\frac{6636\,(180 + 186)\,100}{(5 + .01)^{2.1}\ddagger}\right)^2} = \sqrt[3]{\left(\frac{2\,428\,736 \times 100}{29.489}\right)} = \sqrt[3]{8\,236\,210^2} = 40784 \text{ lbs.}$$

* A point of the globe directly under our feet, or that opposite the zenith.

† Standard of comparison.

‡ For $(5 + .01)^{2.1}$, see p. 310. Thus, $\frac{5.01 \times 21}{10} = \frac{21}{10} \times \log. 5.01 = 2.1 \times .699\,837 =$ *Number* 29.489

When the Object is not in a Vertical line with the Explosion.

ILLUSTRATION.—Assume a charge of gun-cotton weighing 882 lbs., set in water, at a horizontal distance of 24, and a vertical of 86 feet from the object; what would be the effect?

To obtain Δ, or angle of divergence, $180° - \text{Tan.}^{-1}\frac{24}{86} = 15°\ 25'$, and $180° - 15°\ 25' = 164.58°$. $D = \sqrt{24^2 + 86^2} = 89$, and $E = 135$. Hence,

$$\sqrt[3]{\left(\frac{6636\,(164.58 + 135)\,882}{(89 + .01)^{2.1}}\right)^2} = P$$

$= 3.821\,906$ | Log. of $89 + .01 = 1.949\,439$

...58 + 135 $= 2.476\,513$ | $\times\ 2.1$

$2.945\,469$ | $1\,949\,439$

...43 888 | $38\,988\,78$

...3 822 | Log. of $89.01^{2.1} = 4.093\,8219$

...0 066

2

...0 132

... number 2712.5 lbs. = P.

Efficiency of Water-Tube Steam-Boilers.

a late test by J. J. Thorneycroft of his patented boiler, the following elements results are reported to the Institute of Civil Engineers. See Vol. XCIX., 1889.

gine.—Triple expansion, Cylinders 14, 20, and 31.5, by 16 ins. stroke of piston, jacketed. Independent engines for Circulating pump, Blower, Donkey, and ring. All exhausting into engine condenser.

Results of Trials.

Elements and Dimensions.	Furnace. Natural Draught.		Blast Draught.		
surface in sq. feet	30	26.2	30	30	26.2
ing " "	1837	1837	1837	1837	1837
surface to grate	61.2	70.1	61.2	61.2	70.1
sure of steam in boiler, p'r sq. in.	200.8	196.3	186	164.2	194.9
" blast in fire-room in ins.	—	—	27	49	2
lutions of engine per minute	192.8	165.2	234.2	268.7	318.4
per sq. foot of grate per hour	11.1	7.74	18.6	29.8	66.8
er evaporated from and at 212° r lb. of coal, ash utilized	—	11.22	10.48	10.2	8.89
o. do. per lb. of carbon	—	13.08	12.18	11.7	10.04
o. do. per sq. foot of ating surface per hour	—	1.24	3.2	4.7	8.05
perature of gases in chimney	474°	421°	540°	610°	777°
" of air in fire-room	—	69.3°	71.4°	60.3°	62.1°
per IHP per hour	2.22	2.28	1.981	1.99	2.26
on " "	2.28	2.334	2.03	2.04	2.32
" "	150.3	89.1	282.1	449.2	774.7
ency of boiler per cent	—	86.8	81.4	78.2	66.6
r used for jacket per IHP per ir in lbs.	1	1.43	.84	.42	.38

el. Calorific value of 14 900 thermal units per lb., equal to 1.025 of a lb. of car- Each lb. of coal, if completely consumed, is capable of evaporating 15.41 lbs. r from and at 212°.

Barbed Steel-wire Fencing. (*Galvanized or painted.*)

J. A. Roebling's Sons Co., New York.

ur points, barbs 6 inches apart, 15 feet = 1 lb.
" " " 3 " " 12 " = 1 "

Spools.—15 feet in length of the regular measures and 12 feet of the thickset, h each one lb.

ool, about 18 × 18 × 17 ins., measuring 3.5 cube feet, weighing from 60 to 100 and length of wire ordinarily 1500 feet. Thickset or Hog weighs .2 more.

Compute Volume of Boards that can be Sawed out of a Round Log. (*M. J. Butler*, C.E.)

LE.—From diameter of log in inches subtract 4, multiply remainder by one of it, multiply proceed by length of log in feet, and divide product by 8; result give number in feet.

$\overline{-4} \times \frac{d}{2} \times l \div 8 = V.$ *d representing least diameter in inches, l length of log t, and* V *volume in feet of board measure.*

USTRATION.—Assume a log 30 ins. in diameter and 15 feet in length.

$$30 - 4 \times \overline{26 \div 2} \times 15 \div 8 = 633.75 \textit{ feet } \text{B.M.}$$

oot-Pound—*When for Unit of Work*—Is 1 lb. lifted, thrust, or projected gh 1 foot, against gravity or inertia, and is expressed in pounds or tons, with- egard to the period of its action.

hen for Unit of Rate of Work—Is 1 lb. lifted, etc., as above, 1 foot in a given *l, as in 1 second or minute.*

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Results of Trials.

.nd Dimensions.	Furnace. Natural Draught.		Blast Draught.		
. sq. feet...........	30	26.2	30	30	26.2
"	1837	1837	1837	1837	1837
to grate...........	61.2	70.1	61.2	61.2	70.1
n in boiler, p'r sq. in.	200.8	196.3	186	164.2	194.9
in fire-room in ins.	—	—	27	49	2
:ngine per minute..	192.8	165.2	234.2	268.7	318.4
of grate per hour..	11.1	7.74	18.6	29.8	66.8
d from and at 212°, ash utilized	—	11.22	10.48	10.2	8.89
per lb. of carbon..	—	13.08	12.18	11.7	10.04
per sq. foot of :e per hour......	—	1.24	3.2	4.7	8.05
gases in chimney..	474°	421°	540°	610°	777°
air in fire-room....	—	69.3°	71.4°	60.3°	62.1°
r hour............	2.22	2.28	1.981	1.99	2.26
"	2.28	2.334	2.03	2.04	2.32
"	150.3	89.1	282.1	449.2	774.7
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acket per IHP per	1	1.43	.84	.42	.38

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8 × 18 × 17 ins., measuring 3.5 cube feet, weighing from 60 to 100 of wire ordinarily 1500 feet. Thickset or Hog weighs .2 more.

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.nd—*When for Unit of Work*—Is 1 lb. lifted, thrust, or ıgainst gravity or inertia, and is expressed in pounds or e period of its action.

' *of Rate of Work*—Is 1 lb. lifted, etc 1 foot ond or minute.

Wire Rope.*

Galvanizing **decreases strength of unannealed wire 5 per cent., and its ductility 15 per cent.**

Breaking Weight **of No. 20, B W G (.035 in.) crucible steel rope of 6 strands, 1¾ ins. in circumference: Wires, 78 to 102 tons per square inch, and Ropes 55 to 10.47 tons.**

Annealed Wire **is not affected by galvanizing, but its ductility is reduced from 179 twists to 58, = 68 per cent.**

Annealing Wire **reduces its strength 45 per cent., but increases its elasticity 77 per cent.**

Tensile Strength **of crucible steel wire averages 85 tons (80 to 90) per sq. inch.**

Permanent set, Bessemer iron wire 12 tons per sq. in., or .25 of ultimate tenacity.

Variation of tensile strength of like pieces of steel wire, galvanized or plain, is but 3 per cent. for the former and 8 for the latter.

Modulus of Elasticity **(ME). Iron wire 22 400 000, Steel 35 000 000, and crucible Steel 33 000 000.**

Bending. **Stress due to it, in a wire of the material and dimensions given.**

ME = 32 000 000.

Diam. of pulley............	10.5	13.125	16.875	18.75	24 ins.
Stress per sq. inch.........	50	40	31.4	28.2	22 tons.

Durability. **Life of steel wire ropes over iron pulleys, of material and dimensions above.**

Number of times rope passed over the pulleys without Breaking. Load **1568 lbs.**

	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Diam. of pulley ...	5.25	7.875	10.5	13.125	16.875	18.75	24
Number of times..	6075	10 300	16 000	23 400	46 800	72 700	74 [illegible]
	—	—	53 100†	85 200†	—	392 500†	336 [illegible]

Over Pulleys 24 Inches in Diameter. Load 1568 Lbs.

Manufacture of T. & W. Smith.	B W G	Diameter.	Number of Bends before Breaking. Wire and strands laid in opposite direction. 1-24 Inch.	3-24 Inch.	Wire and strands laid in same direction. 3-24 Inch.
	No.	Ins.	No.	No.	No.
Ordinary crucible steel.....	20	.035	74 100	51 000	126 000
Patent improved steel......	20	.035	96 000	57 000	142 800
Plough steel...............	20	.035	109 000	54 000	134 400
Iron wire..................	19	.042	66 000	32 000	79 000
Crucible steel..............	18	.049	87 000	47 400	117 100
Crucible steel..............	22	.028	111 000	48 700	120 300

NOTE.—By author: diameter of pulleys should be = 10 circumferences of rope.

Tenacity of Dovetails.

White Pine, 6 inches square. Notch in Length equal to Depth of Timber.

S and D *each representing proportion or depth of cuts to width of*

	Destruction.		*Destruction.*
S .25	3.9 tons.	D .125	6 tons.
.33	5.75 "	.167	6 "
.41	5.1 "	.208	6 "

trength in a double dovetail is attained when D = .167, and in a single, (*Gen'l O. M. Poe, U. S. E.*)

Shafting for Lathes and Mills.

iould be given in inches or quarters only. *Length.*—Not to exceed *ty.*—Machinery, 125 to 150 revolutions per minute; Woods, 200 to ıpplied at middle of length of shaft whenever practicable. *Hangers* ble boxes, in order the easier to maintain a shaft in line.

—art. Ins'n C.E. † Long's patent lay.

Cost of Sawing and Dressing Stone.

Sawing.

Per Cube Foot.

lford Stone.—20 cents. At Chicago, *Soft*, medium, 8 to 10 cents; **estone, Magnesian, and Oolites.**—*Medium*, 13 to 17 cents; and **Granite**, *Hard*, 25 to 30 cents.

Rate in 10 *Hours.*

	Ins.		Ins.		Ins.
....	12	Marble, Tenn...	9	Limestone..........	10 to 15
ne	8	" Vermont.	20	" magnesia.	36
one.....	36 to 40	Brownstone....	20 to 25	" oolite....	40 to 70

.—Depth of cut without reference to its length or number of saws. (*R. J.*

Dressing.

Per Square Foot. Labor $ 3 *per Day.*

rd Limestone.—Bush hammered, rough, 25 cents; Medium work, s; Fine work, 35 cents.

Cost of Raising Water.

000 Imperial or 1 200 000 U. S. Gallons 1 Foot.

Average of 15 *Years.*

Low Service.	*High Service.*
er, 1.23 cents. By steam, 13.2 cents.	By steam.... 25 cents.

Adhesion of Drifted Bolts.

Steel, One Inch in Diameter.—Hole Six Inches in Depth.

Wood.	Mean Holding Resistance per Lineal Inch.				Ratios.			
	Hole 15-16ths.	Hole 14-16ths.	Hole 13-16ths.	Hole 12-16ths.	Hole 15-16ths.	Hole 14-16ths.	Hole 13-16ths.	Hole 12-16ths.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
pine......	361	616	761	400	.47	.8	1	.53
oak.......	1300	1778	2499	1133	.52	.71	1	.45

lock in 15-16ths hole 415 lbs. per lineal foot to withdraw it, and White or y Pine 12-16ths hole 830 lbs.

btain maximum holding resistance of timber, diam. of hole to bolt as 13 to 16.

tive holding resistance between driving parallel or perpendicular to the fibre to 2. (*J. B. Tschamer.*)

Resistance of the Air to Falling Bodies.

Falling Body In Vacuo.		Lead Ball, 2 ins. in Diameter, Weight 1 lb. In Air.			Body Falling Horizontally. Weight 1 lb. One Foot Square.			Two Feet Square.		
Velocity.	Fall.	Final Velocity.	Fall.	Retardation per Sec.	Final Velocity.	Fall.	Retardation per Sec.	Final Velocity.	Fall.	Retardation per Sec.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
16	32	30	15.5	.5	28	14.33	1.66	13.33	13.33	2.66
48	64	55	43.5	4.5	35	33	15	24	37.3	24
80	96	77	67.5	12.5	38	38.5	41.5	—	61	66.66

(*P. H. Van Der Weyde.*)

rdation is Inversily as Density of Body. Velocity after fall of one seco es measureably uniform; the increased velocity being balanced by the i d resistance.

stance of the air at moderate velocities, to the velocity of a f uare of its velocity.

, when the velocity is doubled, the resistance is quadruple *e times greater.* Applicable alike to a cannon ball in air o

4 L

Cost of a Horse-Power by Steam.*

Joule's equivalent (p. 504) = 772 *units* = heat required to raise 1 lb. water 1°, = elevation of 1 lb., 1 foot high.

Unit of evaporation, to evaporate 1 lb. water to steam at the pressure of the atmosphere = 966.1 British thermal units.

Horse-power 33 000 lbs.

$\frac{33\,000}{772} = 42.75$ *heat units* = 1 IP 1°, and 42.75×60 min. = 2565 per IP *per hour*.

$\frac{2565}{966.1} = 2.655$ *lbs.* water required to generate 1 IP.

Anthracite coal has.... 14 500 heat units.
Bituminous " British. 14 320 " " } For other fuels see p. 486.

Then $\frac{14\,500}{966.1} = 15.01$ *lbs. water* evaporated per lb. of coal.

Hence, $\frac{2.655}{15.01} = .1769$ *lbs. coal* per IP per hour, or $\frac{1}{.1769} = 5.65$ IP *per hour* per lb. of coal.

Assuming in all of the above, the normal condition, that there is neither expenditure of water or temperature in the operation.

Operatively.—From elements furnished, in part by Thos. Pray, C. E., the cost of a IP at the pressures and expansions given is as follows:

Coal at $ 3 per 2000 lbs.

Engine.	Condensing. 20″×48″	Non-condensing. 18″×42″
Initial pressure of steam	83.6 lbs.	58.5 lbs.
Cut off	— ins.	4.74 ins.
Terminal Pressure	8.71 lbs.	8.12 lbs.
Evaporation per lb. of coal	10.31 "	9.99 "
" " IP	16.84 "	18.59 "
Coal per IP per hour	2.28 "	2.07 "
Cost per IP per 10 hours	2.6 cents.	6.21 cents.

A Condensing Pumping Engine has been operated at a cost of 2.28 cents.

* *For Horse-power see pp.* 441, 733, 758, *and* 914.

Cost of Water Power on Driving Shaft.

Per IP.

Power is variable, depending upon variation in head of water, as when it is delivered in a river subject to rise by freshets, cost of water, and of plant. In order to attain an average daily power, the power must be increased to meet the loss of head by back water in freshets.

Location.	IP	Distance from Supply to Wheel.	Average Head.	Cost per IP	Location.	IP	Distance from Supply to Wheel.	Average Head.	Cost per IP
	No.	Feet.	Feet.	$		No.	Feet.	Feet.	$
Manchester, N. Y.	890	30	30	44	Lowell, Mass.	1000	575	13	100
Lawrence, Mass.	1000	490	28	42	" "	1000	290	18	57

Cost of a 1000 IP Plant independent of cost of water about $ 45 per IP.

Cost of a like Plant under different Heads.

Head.	From Supply to Discharge in Feet. 100	200	300	400	500	600	Head	From Supply to Discharge in Feet. 100	200	300	400	500	600
Feet.	$	$	$	$	$	$	Feet.	$	$	$	$	$	$
10	95	110	125	140	155	170	30	26	32	39	45	51	58
20	38	46	54	62	70	77	40	20	25	31	37	42	48

At Lawrence and Lowell, a Mill Power = 30 cube feet of water per second, with a head of 25 feet. At Manchester it is 38 cube feet, with a head of 20 feet.

(Chas. T. Main, M.E.)

a Mill Wheel see pp. 565, 566.

Steam Plant.

Daily and Yearly Cost of Coal and Labor in Operating a Plant of 1000 HP.

Year of 308 days of 10.25 hours, coal at $3 per ton of 2000 lbs.

Deduced from Reports of Chas. T. Main, M.E.

Engine.	*Exhaust steam used.	Coal per HP per hour.	Attendance and Stores per HP per Day. Boiler.	Engine.	Stores.	Coal per HP per day.	†Daily per HP	†Daily for 1000 HP	Yearly.
	Per cent.	Lbs.	c	c	c	$	$	$	$
Compound..	0	1.75	.53	.60	.25	2.14	3.52	3 520	10 841.60
	25	1.5	.45	.60	.25	1.84	3.16	3 160	9 732.80
	50	1.25	.38	.60	.25	1.53	2.76	2 760	8 500.80
Condensing.	0	2.5	.75	.40	.22	3.06	4.43	4 430	13 644.40
	25	2.06	.62	.40	.22	2.52	3.76	3 760	11 580.80
	50	1.63	.49	.40	.22	2	3.11	3 110	9 578.80
Non-Condensing...	0	3	.90	.35	.20	3.67	5.12	5 120	15 769.60
	25	2.44	.73	.35	.20	2.99	4.27	4 270	13 151.60
	50	1.88	.56	.35	.20	2.3	3.47	3 470	10 687.60

* For heating. † Including coal.

Yearly Cost of 1000 HP and of a HP.

Year of 308 days of 10.25 hours. Coal at $3 per ton of 2000 Lbs.

Deduced from Reports of Chas. T. Main, M.E.

Engine.	*Exhaust Steam used.	Engine and House.	†Operating Expenses.	Boiler-house and Shed.	†Operator's Expense.	‡Coal and Labor and Stores.	§Total per HP
	Per cent.	$	$	$	$	$	$
Compound....	0	40	5.02	18.36	2.50	10 841.60	18 361.60
	25	40	5.02	16.16	2.20	9 732.80	16 952.80
	50	40	5.02	13.90	1.89	8 500.80	15 410.80
Condensing...	0	33	4.14	24.80	3.38	13 644.40	21 164.40
	25	33	4.14	21.12	2.88	11 588.80	18 608.80
	50	31	3.95	17.33	2.36	9 578.80	16 888.80
Non-Condensing.........	0	29.50	3.70	24	3.95	15 769.60	23 419.60
	25	29.50	3.70	24.28	3.31	13 151.60	20 161.60
	50	29.50	3.70	19.46	2.65	10 687.60	17 037.60

* For Heating. † Injector, Depreciation, Taxes, Interest, and Insurance.
‡ As per previous Table. § Not including Cost of Plant in column 3 and 5.

Sugar in Mortar.

It has been demonstrated that the addition of saccharine matter to lime-mortar is very beneficial, as it enables it to be laid in frosty weather.

It is claimed also that it causes the mortar to set very soon and strengthens it, and that it can be laid with dry bricks.

As sugared water dissolves lime, it is necessary to dissolve the sugar first, and then add the water to the lime slowly and cautiously. The mortar should be very stiff.

Proportions.—For mortar, coarse brown sugar, 2 lbs.; lime, 1 bushel; sand, 2 bushels.

If sugar is added to mixed mortar, it renders it too thin. (*Manufacturer and Builder.*)

Belting. Speed of belts, single and double, 1 inch in width, sho
ceed for the first, 800 feet per minute, and for the second 500 feet, eac

Railroad Speed.

London, North Western, and Caledonian.

London to Edinburg, 400 miles. Speed, 55.4 miles per hour; w.
miles. Engine, Tender, and Cars, 348 000 lbs.

Cost of Irrigation per Acre.

California.—From $7.18 to $53.33. *Colorado.*—$3.75 to $10.80. *Utah,* $4. *France.*—Average of several, $58. *India.*—Average of several, $1.75 to $10.

Alloy

That expands in cooling: Lead 9 parts, Antimony 2, Bismuth 1.

Extremes of Temperature.

Artificial, 135° (*Faraday*). Atmosphere, 77° (*Back*).

Extension of Woods by Water. (*de Volson Wood.*)

Elongation.	Pine...... .065	Lateral.	Pine...... 2.6
	Oak...... .085		Oak...... 3.5
	Chestnut.. .165		Chestnut.. 3.65

Smokeless Powder. Gun 6 ins. in diam. Charge 17.64 lbs. Energy at muzzle, 4609 foot-tons. Per lb. of powder 139.7, and per weight of gun 720.

Volume of Water Flowing over Niagara Falls.

270000 cube feet per second. Since 1842, Horseshoe Fall has receded 140.5 feet, and American 36.5 feet. (*J. Bogart, S. E.*)

ROOFS.

To Compute Stress on Roofs.

Velocity and Pressure of Wind.

RULE.—Multiply square of velocity of wind in feet per second by .0023, or square of its velocity in miles per hour by .005, and product will give pressure in pounds per sq. foot.

$$\text{Or, } v^2 \times .0023 = P, \text{ and } V^2 \times .005.$$

Also, $.0023\, v^2 \sin. x = P$. P *representing pressure per sq. foot in lbs., x angle of incidence of wind with plane of surface in degrees,* V *velocity of wind in miles per hour, and v velocity in feet per second.*

Direction of wind usually makes an angle of 10° with the horizon, hence 10° is to be added to horizontal plane of direction of the wind.

ILLUSTRATION 1.—Assume wind with a velocity of 100 feet per second to impinge upon a plane roof set at an angle of 45°; what would be the pressure per sq. foot?

$$\text{Sin. } 45° + 10° = .819. \qquad .0023 \times 100^2 \times .819 = 18.837 \ lbs.$$

2.—Assume the wind to have a velocity of 150 feet per second, and angle of roof 60°; what would be the pressure per sq. foot?

$$\text{Sin. } 60° + 10° = .94. \qquad .0023 \times 150° \times .94 = 48.75 \text{ lbs.}$$

Pressure of Snow.

This pressure decreases per square foot in *Ratio* of half space, to length of rafters, or height divided by space.

Pressures for Various Angles or Ratios.

At 15 Pounds Weight per Square Foot.

h ÷ s	Degrees.	Lbs.	h ÷ s	Degrees.	Lbs.	h ÷ s	Degrees.	Lbs.
.5	45°	10.6	.2	21° 48′	13.9	.125	14° 2′	14.5
.33	33° 40′	12.6	.16	17° 45′	14.3	.11	12° 31′	14.6
.25	26° 34′	13.4	.14	15° 39′	14.4	.10	11° 19′	14.7

Weights on Roofs.

Per Square Foot in *Lbs.*

Iron, sheet..........	8	Iron, corrugated, on iron	43
Zinc, sheet..........	8	Zinc " "	41
lates on iron.......	10	Snow....................	20
ron, sheet on iron ..	5	Wind....................	10

arative Operations of a Simple and a Compound Locomotive.

klyn and Union Elevated Railway of Brooklyn, N. Y. Forney Type.

ENTS.	Simple.	Compound.	ELEMENTS.	Simple.	Compound.
, ins.....	11×16	11.5 18×16	Coal per car mile.	11.05 lbs.	6.88 lbs.
liam.....	42 ins.	42 ins.	Water...........	26 070 lbs.	19 862 lbs.
revolu- r mile	480	480	Gain in fuel......	—	37.7%
im......	42 ins.	42 ins.	Evaporation from 212°	8.09 lbs.	9.97 lbs.
) D......	1.5 ins.	1.5	Gain in water....	—	23.8%
f........	124	124	Water per car mile	73.85 lbs.	56.27 lbs.
ip, diam.	3.25 ins.	3 ins.	Pressure of steam, ave'	136 lbs.	136 lbs.
ater.....	—	—	Revolu's per min.	—	222
feet...	15.6	15.6	Miles per hour...	—	27.73
urface, ...	289.46	289.46	HP.............	—	223.6
do. to	18.5	18.5	Weight, loaded...	45 350	45 850
....	3899 lbs.	2430 lbs.	Miles run........	122	122

High Explosives.

Firing Point and Relative Strength.

GNATION.	Firing Point.	Order of Strength.	DESIGNATION.	Firing Point.	Order of Strength.
	Degree.			Degrees.	
it. (Vouge's).	365	106.17	Tonite...............	—	68.24
e...........	—	106.17	Bellite...............	—	65.7
erine (old)..	365	100	Rack-a-rock	—	61.71
fresh ...	—	92.37	Atlas powder.........	—	60.43
French .	—	81.85	Ammonia, dynamite..	—	60.25
owder (Nobel)	—	92.38	Volney's powder No. 1	—	58.44
n, 1889......	346	83.12	" " No. 2	—	53.18
laboratory	—	81.31	Melinite	—	50.82
No. 1.......	—	81.31	Fulminate, silver.....	—	50.27
te No. 1.....	301	77.86	" mercury..	315	49.91
. Picric acid.	—	69.51	Mortar powd., Dupont	500	23.13
wder........	—	69.87	Forcite No. 1.........	330	—

(*Lieut. W. Walke, U. S. Army.*)

Electrical. (*Additional to p.* 34.)

Units in Electrical Engineering.

tance.—The ***Ohm***, symbol ω, equal to the resistance of a column of ury 106.3 cms. long, and 1 □mm. in uniform cross-section at 0° C. , symbol Ω, 1 000 000 ohms. ***Microhm***, one millionth of an ohm.

ent.—The *Ampere*, that strength of current that will transfer 1.1181 mes of silver per second between electrodes of pure silver immersed in s 20 to 30% solution of pure silver nitrate.

ives: *Kilo-ampere, Hecto-ampere, Deca-ampere, Deci-ampere, Centi-am i-ampere, Micro-ampere.*

ro-motive Force.—The ***Volt***, the EMF. which will force one ugh a circuit of one ***ohm*** resistance. Derivative, ***Microvolt.***

city (Electrostatic).—The ***Farad***, Φ, the capacity of a condenser th Coulomb, under a difference of potential of one ***volt***. Deriv., ***Microfa***

.—The ***Joule***, the work done by transferring one ***Coulomb*** age ne volt.

ives: ***Kilojoule, Millijoule, Microjoule.***

of Working.—The ***Watt***, the rate of second. Derivative, ***Kilowatt.***

tance.—The ***Henry***, H, 1 000 000 000 centim

ves: ***Millihenry, Microhenry.***

STEAM-ENGINES.

Compound.

Duration of Operation 2 Hours.

Cylinders.—5.5, 9, and 15.5 ins. in diameter. Stroke of piston 14 ins.

Revolutions.—150 per minute. IHP 40.

Boilers.—Fire tubular. *Tubes*, 38 of 2 ins.; 6.25 feet in length.

Heating Surface.—158 sq. feet. *Grates.*—5.7 sq. feet.

Pressure of Steam.—175 lbs. per sq. inch.

Water.—Weight consumed, 1140 lbs. *Evaporation* per lb. of coal, 9.8 lbs. Drain from jackets, 84 lbs. *Consumption* per HP per hour, 1.425 lbs. Temperature of feed, 55°.

Consumed 116 lbs.—per IHP per hour 1.45 lbs.; per sq. foot of grate 10.2 lbs.

Indicator Diagrams.—Mean HP 54 = 13.31 IHP; Intermediate 18 = 12 IHP; Condensing 7.5 = 14.7 IHP = 40.

Fly-wheel.—5.5 feet in diameter and 10.5 ins. in width.

Weight of Engine and Boilers, without water, 14 560 lbs.

Builders.—Marshall & Co., Kreigly, Eng.

PUMPING ENGINE.

Vertical Compound.

Cylinders.—34 and 66 ins. in diameter by 60 ins. stroke of piston.

Pressure of Steam.—74.81 lbs. per sq. inch. *Vacuum*, 26.25 ins.

Revolutions.—25.51 per minute. *Grate Surface.*—70 *sq. feet.*

Pressure of Water by Gauge. — 62.02 *lbs.* Head, including lift, 155.17 *feet* = 67.62 *lbs.* *Fuel.*—675 lbs. per hour.

Duty.—104 820 431. *Stack*, in height, 125 *feet.*

Constructors.—The Edward P. Allis Co., Milwaukee, Wis.

ELECTRIC DYNAMO ENGINE.

Triple Expansion.

Arc Lights.—500. Water entrained in steam 7.39%.

Cylinders.—14, 25, and 33 ins. in diam. by 48 ins. stroke of piston.

Condenser.—Separate. *Circulating Pump*, 16 × 16 ins.; *Air-pump*, single-acting 24 × 16 ins. *Cylinders*, 12 × 16 ins., operating both pumps. Revolutions, 61.29 IHP 16.4.

Pressure of Steam.—125 lbs. per sq. inch; *Revolutions*, engine, 99.12; *Steam* per IHP per hour, 12.94 lbs. IHP 516. *Injection Water.*—72°. Reservoir, 90°.

Constructors.—The Edward P. Allis Co., Milwaukee, Wis.

Railroad Signals and Significations.

op," one pull of bell-cord.

ahead," Two pulls.

ack up," three pulls.

own breaks," one whistle.

"Off breaks," two whistles.

"Back up," three whistles.

"Danger," continued whistles.

"A cattle alarm," rapid short whistles.

ahead," a sweeping parting of the hands, on level with the eyes.

k slowly," a slowly sweeping meeting of the hands, over the head.

," downward motion of the hands with extended arms.

," beckoning motion of a hand.

ger," a red flag or light waved up the track.

" red flag raised at a station.

[illegible] raised and lowered vertically.

ight angels across the track.

ung in a circle.

Opera House, New York.

nding, 400. If the saloons attached to the private apacity would be 5000.

Distillation of Fresh Water.

Process of G. W. Baird, U. S. Navy, New York.

Marine Steamers for long voyages, operated under a high pressure of steam, are necessarily provided with Evaporators, to replace the water expended in leaks and vents, and to provide for the ordinary requirements for fresh water.

This process is an improvement upon existing methods, inasmuch as it furnishes the water potable, and it is as follows:

The *Evaporator* contains a series of tinned metallic coils and a volume of sea-water; which is designed to be evaporated by the passage of steam from the engine boilers through the coils. The water condensed in them is returned to the boilers; the water vaporized from the sea-water, external to the coils, is either led to the Engine condenser, to replenish that lost by leaks and vents, as from gauge cocks, etc.; or if required for potable purposes, is led to a *Distiller*, where it is aerated, condensed, and filtered, from which it is drawn for use.

As the sea-water is evaporated in vacuo, vaporization occurs at a temperature below that at which much scale is precipitated. Hence the shell and coils are both measurably free from it.

Results of an Experiment.

Pressure in coils, 20 lbs. above atmosphere; *temperature of steam in coils*, 259.3°; *temperature of feed water*, 131.66°; *temperature of the water vaporized*, 212°; *water vaporized* per hour, 103.33 lbs.; *water condensed in the coils* per hour, 112.12 lbs.; *total heat* in the steam, 1193.7°, and in the water vaporized, 1178.6°.

Capacities of Evaporators and Distillers.

Gallons per day of 24 hours.

No.	Evaporator.	Distiller.	No.	Evaporator.	Distiller.	No.	Evaporator.	Distiller.	No.	Evaporator.	Distiller.
	Gallons.	Gallons.		Gallons.	Gallons.		Gallons.	Gallons.		Gallons.	Gallons.
1	600	600	3	2000	1600	4	3000	2000	5	4000	2500
2	1200	1200	3.5	2000	1600	4.5	3000	2500	6	6000	3000

Coal Production and Consumption

Of the World Per Diem.

Production.—Estimated at 3 360 000 000 to 3 696 000 000 lbs.

Consumption.—Generation of steam, Land and Marine, 624 000 000 lbs.; Smelting Iron Ore, 28 800 000 lbs.; other metals, 23 000 000 lbs.; Forges, 20 000 000 lbs.; Domestic use, 57 600 000 lbs. Total, 2 700 000 000 lbs.

Corrosion of Wrought Iron.

The purer the water, the more active it is in corroding and pitting Wrought-iron plates. This arises from the greater presence of air in pure water, and hence a greater proportion of Oxygen. (*Locomotive.*)

Earth Boring and Heat of Mines.

Sperenberg, near Berlin. Bore, 4172 feet in depth, about 1000 feet in excess of Artesian well at St. Louis.

In lower levels of some of the shafts in the Comstock mines, prior to the draining into the Sutro Tunnel, the water was at a temperature of 120°.

Preservatives of Iron.

Pitch, Black Varnish, Asphalt and Mineral waxes are among the best, provided the acid and ammonia salts, which frequently occur in tar and tar products, are removed.

If in addition these substances are applied hot to warm ... minous and asphaltic substances form on the surface of the iron an ... nlike to other coatings, is not microscopically porous, and consequ ... to water.

Spirits and Naptha varnishes are injurious. (Prof. Le...

Felting, Covering, Lagging, etc.

Steam Pipe and Boiler Coverings, etc.

In the protection of heated surfaces, or from freezing, Hair-Felt, in consequence of its destructibility at high temperatures and the loss in removing it for repairs or the arrest of leaks in boilers or pipes which it covers, has very generally been superseded by the adoption of Asbestos fibre with its composition with other materials and conformations, whereby it is rendered available for all requirements of, as well as conformable to, the several and various conditions in which it is required.

Asbesto-Sponge.—Composed of the fibres of Asbestos and common sponge, by which combination porosity is attained and the non-conducting power increased.

Adapted for the lining of Cars, Chests, Floors, Walls, etc., and furnished in barrels and bags containing 25 lbs.

Asbestos, Cement Felting.—Composed of Asbestos fibre, infusorial earth, and a cementing compound, applied to pipes, boilers, etc., while heated.

Furnished in barrels and bags. One bag will supply material to cover a surface of [illegible] inch in thickness, and weighs about 150 lbs.

Asbestos Roll and Sheet Fire-Felt.—Composed wholly of Asbestos, similar in texture to hair-felt, can be readily cut and applied.

In Rolls of 300 □ feet, 3 feet in width, and from .093 78 to .25 ins. in thickness.

The *Sheet felt* is furnished in sections, in order that they may be removed and replaced, and are especially adapted for Marine Boilers.

In Sheets, 2 by 3 feet, and from .5 to 1.5 ins. in thickness.

Asbesto-Sponge, Molded, Fire-Felt, and Standard Sectional Coverings.—The *Sponge* and *Molded* are adapted both for low and high pressure of steam, felted and formed in cylinders, cut lengthwise, so that they may be laid over pipes, and are finished with a canvas jacket, secured by metal bands.

The *Fire-Felt* is adapted for high pressures and Superheated steam. The *Standard* is composed of alternate layers of Asbestos sheathing and soft-wool felt [illegible] together, and is adapted for medium pressures of steam.

In Sections, 3 feet in length, with bands, staples, and straps for securing Elbows, Tees, etc., [illegible]

"National," Removable, Air-Chamber, and Frost Protective Sectional Coverings.—"*National*" is composed of wool felt, lined on the inside and alternated for three layers with Asbestos [illegible] felt, and it is an economical covering for low pressures of steam and steam [illegible] pipes. *Removable* is composed of hair-felt and Asbestos of equal thickness, [illegible]oped in a case of wool sheathing and a lining of Asbestos.

In Sections of 3 feet in length, with straps and staples to secure.

Asbesto-Sponge Lined and Asbestos Lining Felt. Suitable for Furnaces, Furnace Pipes, and Fire-heated surfaces.

In Rolls, from 12 to 36 inches in width, and 50 feet in length.

Asbesto-Sponge Hair-Felt.—Is very elastic, and, in consequence of the large proportion of Asbestos in it, it is not liable to injury from steam heat.

In Rolls of 250 □ feet, and .25 ins. in thickness.

Superator.—An Asbestos fire and water proof sheet has a foundation of [illegible] through which Asbestos is pressed and the sheet rendered waterproof by a [illegible]cial process. It is suited for ceilings, walls, partitions, and all surfaces exposed to fire and water.

In Rolls of 300 □ feet, 39 ins. in width.

Corded Sheathing.—For fire-heated surfaces, of pure Asbestos, [illegible] face of which are attached loosely twisted rolls of it, forming a material [illegible] inch in thickness, suitable for Furnaces, Furnace Pipes, etc.

Rolls of 100 and 150 □ feet, and 3 feet in width.

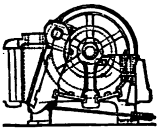
Locomotive Lagging.—Of pure Asbestos, woven with a [illegible] with a pure Asbestos sheathing. It is fire and acid proof.

Rolls of 36 inches in width and .5 inch in thickness.

Cap Hair-Felt.—Of various thicknesses, in bales of 300 □ ft. and [illegible] boxes

Stone Breaker and Ore Crusher.

Farrel Foundry and Machine Co., Ansonia, Conn.



Stone Breakers and Ore Crushers are used in making Macadam for construction of roads; material for concrete; ballasting railroads, crushing ores, quartz, corundum, and all brittle substances; they can be adjusted to pass a mass from the size of a pea to larger diameters, depending upon the capacity of the machine.

Crushed to Cubes of 2 Inches. Per Hour.

No.	Receiver.	Volume.	Extreme Weight of Stone.	Weight Produced.	Dimensions. Length.	Breadth.	Height.	Pulley.	Speed.	HP
	Ins.	Cub. yds.	Lbs.	Lbs.	Ft. ins.	Ft. ins.	Ft. ins.	Ins.		No.
1	3× 1.5	—	40	100	1. 1	. 6	.10	5× 1	250	.5
2	6× 2	1	560	1 200	2.10	2. 1	2. 3	11× 5	250	4
3	10× 4	3	1800	4 900	4	3. 3	3. 9	20× 6	250	6
4	10× 7	5	3800	7 800	5. 1	3. 9	4. 5	24× 7.5	250	8
5	15× 9	8	7400	15 500	6. 6	5	5.11	30× 9	250	15
6	15×10	9	7800	16 000	6. 6	5. 5	5.11	30×10	250	15
7	20× 6	10	5300	11 200	5. 3	2.11	4. 6	30×10	250	15
8	20×10	10	8100	18 300	6.10	5. 9	5.11	36×12	250	20
9	12×30	16	14200	33 000	7.10	8. 4	6. 4	36×12	250	30
10	15×30	20	14200	35 000	7.10	8. 4	6. 4	36×12	250	30

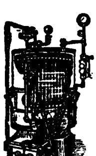
NOTE.—The 30×15 and the 36×24 are preparatory Crushers, the former breaking 00 cube yards in 10 hours to 4 ins., and the latter 800 cube yards to 8 ins.

Crusher with Revolving Screen.

Dimensions.	Volume.	Extreme Weight of Stone.	Weight Produced.	Dimensions. Length.	Breadth.	Depth.	Pulley.	Speed per Min.	HP
Ins.	Cub. yds.	Lbs.	Lbs.	Ft. ins.	Ft. ins.	Ft. ins.	Ins.	Rev.	No.
10× 7	5	3800	10 200	5. 1	3.9	4. 5	2 × 7.5	250	8
15× 9	8	6800	17 700	6. 6	5	5.11	2.6× 9	250	15
15×10	9	7300	18 100	6. 6	5.5	5.11	2.6×10	250	12
20×10	10	7700	21 500	6.10	5.9	5.11	3 × 1	250	14

Steam Heating and Boilers.

Gorton & Lidgerwood Co., New York.



Steam Heating.—Is effected *Directly* or *Indirectly.* In the first case, the steam is conveyed through a pipe, or to a cluster of them, at whatever point they are required, termed a Radiator; air being heated by contact with the exterior surface of the pipes, and the water of the condensed steam flows back (by gravity) through the return pipes discharging into the boiler.

In the second case, steam is conveyed in like manner to a cluster of pipes enclosed in a chamber, in the lowest part of the uilding, usually the cellar, the air within the chamber, upon being heated, scends by its rarefaction, and is led to the space or apartment required to e heated.

Hot-water Heating.—This system consists of circulating hot water n the radiators instead of steam. The boiler, pipes, and radiators are fully illed with water—the flow or circulation pipes attached to the top of the oiler and the return pipes to the bottom. The water in the boiler, when eated, rises and circulates through the pipes and radiators, and parting with portion of its heat it becomes denser, and gravitates through the return ipe to the boiler, where it is again heated.

This system requires a much greater proportion of [illegible] *at of steam.*

Steam-boilers.

ELEMENTS. No.	Wrought-iron Water Legs. 2	3	4	5	6	7	Cast-Iron Legs. 0	1	2
Shell, diam ....Ins.	32	35	41	43	51	54	24	28	32
" over jacket... "	35	38	45	46	55	57	30	31	35
" height....... "	33	37	37	45	45	45	30	33	33
" extreme..... "	69	72	80	87	90	92	64	67	69
Furnace, diam ..... "	21	24	30	32	38	40	18	19	21
Tubes, No., do. 2 ... "	44	56	84	91	124	160	30	36	44
" length ...... "	30	34	34	42	42	42	27	30	30
Steam-outl'ts 2, diam. "	2	2	2.5	2.5	3	3	1.5	1.5	2
Chimney flue, diam. "	8	8	10	10	12	12	7	7	8
Water-line from base "	55	59	63	70	73	74	51	54	55
Heating surface.. □feet	75	105	140	185	260	320	45	60	75
Direct radiating surface supplied "	450	630	830	1050	1500	1900	260	350	450

For Direct radiation, each □foot of radiating surface will heat from 50 to 100 c[illegible] feet of air space, and for Indirect, from 25 to 50 cube feet; the range depending [illegible] the conditions of construction of building and its exposure to external air.

HYDRAULIC CEMENT.

In addition to pp. 589, 590.

New York and Rosendale Cement Co. (*Hiram Snyder, Sec'y*), *New Yor[illegible]*

Cements.—Are classed as natural and artificial; first being used in [illegible]struction of Fortifications, Breakwaters, Aqueducts, Sewers, Bridges, Concrete work of all description, as in Canals, Cellars, Cisterns, and Wa[illegible]

The stone from which hydraulic cement is made in the U. S. is foun[illegible] stratified beds of aqueous deposits, which in extent cover about one thir[illegible] the area of the State of New York, the western part of Vermont, and in New Jersey, Pennsylvania, Maryland, Virginia, and East Tennessee.

The largest deposits of aqueous limestone, producing hydraulic quali[illegible] are located in the Town of Rosendale, Ulster Co., New York.

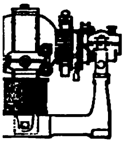
The color and quality of most of the hydraulic cements depend princi[illegible] upon the relative volumes of Oxide of Iron, Lime, Alumina, and Magn[illegible] which may be present; and as these elements are very perceptible in [illegible] highest grades of Rosendale cement, it resembles the celebrated Port[illegible] Cement of England and France.

Tensile Strength. *Per Square Inch.*

Tests.	Area.	In Air.	In Water.	Period.	Tests.	Area.	In Air.	In Water.	Peri[illegible]
No.	Sq. Ins.	Lbs.	Lbs.	Hours.	No.	Sq. Ins.	Lbs.	Lbs.	Hou[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	3	82	65	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	3	86	78	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	87	69	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	3	88	63	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94	74	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	94	77	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99	92	[illegible]

[illegible] 7.9 lbs. per sq. i[illegible]
[illegible] lay, then tested
[illegible]

The Crocker-Wheeler, New York.



This Motor has been designed to remove difficulties which experience has developed to be attendant upon other instruments of like purpose.

Care has been taken in its design and construction. The bearings are oiled automatically, and magnetic circuit is made as perfect as practicable. Its centre of gravity is low, machine strongly built, weight of it comparatively low, and its efficiency high.

ned to run at low speed, in order to reduce wear, heating journals, etc.

ight.	Velocity.	Pulley.		Dimensions.			Between Bolt-holes.		Shafts.	
		Diam	Face.	Length.	Breadth	Height.	Length.	Breadth	Diam.	From Base of Motor.
bs.		Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
18	2100	{G 1.5 / F 1.5	.375 / 1	7.375	5.5	7.875	4.625	2.75	.25	3.375
26	2000	{G .5 / F 1.5	.375 / 1	9.75	7.5	8.5	6.375	3.375	.375	3.6875
26	1800	2.5	1.25	9.75	7.5	8.5	6.375	3.375	.375	3.6875
55	1500	3	2	14.75	9.5	10.75	9.75	4.3125	.5625	4.75
00	1350	3.5	3	18.25	11	13	11.5	5 5	.6875	5.75
57	1050	4	3.5	19	13.25	15.5	12.25	7	.875	7.0625
90	1050	6	3	25	12.625	18.375	18.25	9.25	1	8.25
00	1000	8	4	26.25	15.625	18.375	18.25	9.25	1	8.25
85	1000	7.5	4.5	28	18.75	21	18.75	9.75	1.125	9.25

G Grooved. F Flat.

ation of the Motor —For Printing-rooms and mechanical Shops of medium and Elevators, one of 5 HP is sufficient.

To Compute Power required for Elevators.

—**Multiply twice* product** of weight to be raised in lbs., and height of as-eet per minute; divide by 33 000, and the quotient will give the number of red.

ll Motors, of .166, .125, and .0833 HP are adapted for operating Fans, , **Sewing-machines**, Small Lathes, Presses, Tools, Models in operation, Ro-**dvertisements**, Organ blowing, Baffling wheels, Knife sharpeners, Cloth and **itting, Experimental** models, etc., etc.

Electric Fans.

entilation of Offices, Restaurants, Kitchens, Sick-rooms, etc., etc.

ructed in various styles, Plain and Nickel-plated.

Fans** 12 **Inches in Diameter

ler, .0833 HP motor.— *Fast*, .125 HP motor —*Double* (a Fan at each side), **P motor, or one** 16-inch Fan.

ns Construction.—Variable speed, Fan 24 ins. in diam.—20 *Inch*, 125 HP motor.

Electric Pumps.

HP, will elevate 500 gall. water per day of 10 hours 100 feet in height. **are arranged** to operate automatically, so that when a receiving tank **mp is arrested.**

Capacity of Pump per Hour.

Gallons.	HP	Gallons.	HP	Gallons.
[illegible]	.5	370	3	1670
	1	750	5	2600

Arc Circuit Motors.

ll others. The manner of connecting the circuit a n that of other motors.

.125 to 5 HP.

nnected to the arc circ

1 to cover loss of power

Dynamo Leather Belts.

Belting.—For Dynamos and Electric Light Machinery should [illegible] double and endless, and not over .33 inch thick, when run at a velocity [illegible] 4000 feet or more per minute; should be perforated to prevent air-cushion[illegible] ing, the perforations may be .093 75 inch in width, .281 25 inch in length, and placed 1.5 inches apart; furnishing about 50 openings per sq. foot [illegible] belt, without material injury to the tensile or operating strength of it.

In order to protect the surface of a Dynamo Belt it should be rendered impervious to the mineral oil used on it, which is destructive to the fibre [illegible] the leather.

LEATHER LINK BELTS.

Where Belts are run at right angles and at short distances apart, Leather Link Belts are recommended, as they are very pliable and have uniform oscillation.

Link Belts made .6875 inch thick, forming when combined two full [illegible] cles, assure the required uniformity of oscillation.

WIRES AND CABLES.

Telegraph, Telephone, and Electric Light Wires and Cables.

For Aerial, Sub-marine, and Underground.

The International Okonite Co., Ltd., New York.

Insulation.—In consequence of the decomposing influence of the elements upon insulated wires exposed to them, it is necessary that their insulation should be as perfect in construction and enduring in material as it is [illegible] cable to attain. In order to effect an enduring insulation this Company [illegible] a compound, termed Okonite, a material possessing both tenacity and resist- ance to abrasion, while it is equally unaffected by extremes of temperature, with insulation of a high order.

Telegraph and Telephone Wire.

Size of Insulation and Diameter per B W G; *External Diameter of Insulation in* 32ds; *Weights per Mile in Lbs., and Insulation Resistance per Mile in Megohms.*

No.	Diameter.	Insulation. Gauge	Insulation. External Diameter.	Insulation. Plain. Weight.	Insulation. Plain. Resistance.	Insulation. Braided. Weight	Insulation. Braided. Resistance.
40	24	14	—	29	1000	43	1000
41	24	13	3	33	1200	48	1200
42	22	13	3	45	1000	60	1000
43	20	12	3.5	56	1000	71	1000
44	20	11	4	65	1200	80	1200
45	18	11	4	81	1000	96	1000
46	18	10	—	91	1200	107	1200
47	18	8	5	119	1600	137	1600
48	18	—	6	155	2000	175	2000
49	18	5	7	197	2400	220	2400
50	18	3	8	244	2600	271	2600
51	18	2	9	299	3000	329	5000
52	16	9	4.5	126	1000	143	1000
53	16	8	5	140	1400	158	1400
54	16	7	—	157	1500	176	1500

No.	Diameter	Insulation. Gauge.	Insulation. External Diameter	Insulation. Plain. Weight	Insulation. Plain. Resistance.	Insulation. Braided. Weight	Insulation. Braided. Resistance.
55	16	—	6	164	1600	[illegible]	[illegible]
56	16	6	6.5	178	2000	[illegible]	[illegible]
57	16	5	7	200	2400	[illegible]	[illegible]
58	16	3	8	240	2600	[illegible]	[illegible]
59	16	2	9	288	2800	[illegible]	[illegible]
60	14	8	5	176	1000	[illegible]	[illegible]
61	14	7	5.5	192	1200	[illegible]	[illegible]
62	14	—	6	201	1400	[illegible]	[illegible]
63	14	5	7	236	1600	[illegible]	[illegible]
64	14	3	8	273	1800	[illegible]	[illegible]
65	14	2	9	321	2000	[illegible]	[illegible]
66	12	6	6.5	275	1000	[illegible]	[illegible]
67	12	5	7	300	1500	[illegible]	[illegible]
68	10	5	[illegible]	359	1000	[illegible]	[illegible]
69	10	4	[illegible]	387	1200	[illegible]	[illegible]

Voltmeters and Ammeters.

›ston Electrical Instrument Co., Newark, N. J.

uments are Direct Reading.—A multiplying constant being unnecessary, with voltmeters of high range, as a simple inspection of position of pointer › indicates value in amperes or volts, and as pointer immediately becomes r "dead beat," it reduces period for reading, added to which there does not ›e "magnetic lag" which induces different deflection with like current or al, as in instruments in which vibrating parts are of iron.

›eadings of the scale commence at 0, and the uniformity of the divisions tes the visual subdivision of them.

›ctions for Temperature are unnecessary, as it is for the long coil of the volt- being not in excess of .25 per cent. for a range of 35° above or below 70°, › the ammeter less than 1 per cent. for a like range of temperature.

›it.—These instruments can be retained in circuit without injury, as the › effect, except in the high ranges, is inappreciable.

›rating Coil.—In Voltmeters provided with one, changes in the scale valve ›cidental injury are readily checked.

›he respective parts are made to a uniform gauge, and are interchangeable.

Standard Voltmeters.

›ale in ›olts, up to	Read-able to	Description.	Telegraphic Code.
150	.1	By single volt divisions	Reprint.
150	.1	" " " "	Reprisal.
150	.1	Scale of double values, with ratio of 30.	—
15		Each division on upper scale-values = 1 volt; and on lower scale-values .033 volt, readable to .0033.	Reproach.
150	.1	Scale of double values with ratio of 10.	—
15		Each division on upper scale-values = 1 volt; and on lower scale-values .1 volt, readable to .01.	Reprune.
300	.2	By 2-volt divisions	Reptile.
450	.33	By 3- " "	Republic.
600	.5	By 5- " "	Repulse. Requital.
600	.5	Scale of double values, with ratio of 4, reading by 4-volt divisions, to .5 on upper scale-values; and by	
150	.1	single-volt divisions to .1 on lower scale-values	Resemble.
750	.5	Scale of double values with ratio of 5, reading by 5-volt divisions, to .5 volt on upper scale-values, and by	
150	.1	single-volt divisions to .1 volt on lower scale-values.	Reservoir.
600	.5	Scale of double values, with ratio of 2, readings by 4-volt divisions, to .5 volt or upper scale-values; and	
300	.2	by 2-volt divisions to .2 on lower scale-values.	Reside.
750	.5	By 5-volt divisions	Residue.
1500	1	By 10- " "	Resin.

›s 1.—Calibrating coils and contact keys are attached to instruments only ›o stated.—2. Instruments provided with a contact key can be retained in per- ›t circuit by depressing it and giving it a quarter turn.—3. All instruments ›g above 150 volts are provided with India-rubber-covered binding-posts.—4. ›eters of other ranges and scale-values are furnished as required.

High Range Voltmeters No. 1.

›hese instruments part of the resistance is contained in a separate box, de- ›d to obtain high insulation, and without calibrating coil or contact key.

›s from 0 to 150 volts and a resistance box, multiplying valve of scale divisions.

Volts to 150.	Scale.	No.	Volts to 150.	Scale.	No.	Volts to 150.	Scale.
2250	By 15	15	3750	By 25	17		
3000	" 20	16	4500	" 30	18		

›. Code.—13. Resolute; 14. Resolve; 15. Resolvent; 16. Resona›

›—Above are graduated to read in lamps in additio› ›y simple inspection number of arc lamps open ›› giving intermediate ranges, applicable to these ›.—3. *Reversing Key.* When many and rapid ›› ›*rrents of* unknown polarity are require› ›*lt by turning* the milled head throu› *›rrent in the instrument by an* additi›

Milli-Voltmeters.

No.	Scale in Volts. o, up to	Description.	Telegraphic Code.
1	.02	By 100 divisions, each readable to .1	Restless
2	.01	Right and left by 100 divisions, each representing .0001 volt.	Restrain
3	.01	Right and left by 100 divisions, supplied with contact key, reducing sensibility 10 times	Resume

Volt-Ammeters.

No. 1. Scales 0 to 150 volts and 0 to 1500 mil-amperes. Reading to 150 volts by single-volt divisions, or to 1.5 amperes by .01-ampere divisions.—Retiary.

Mil-Ammeters and Ammeters.

No.	Scale in mil-amperes.	Single-scale divisions, readable	No.	Scale in mil-amperes.	Single-scale divisions, readable
0	150	1 mil-ampere, to .5 do.	3	1000	10 mil-ampere, to 1 do.
1	300	2 do. to .2 do.	4	1500	10 " to 1 do.
2	600	5 do. to .5 do.			

Telegraphic Codes.—0. Reticule; 1. Retinue; 2. Retouch; 3. Reuben; 4. Reunite.

For Physicians.

No.	In volts up to		Telegraph Codes.
5	500 / 50	Scale of double values, with ratio of 10, each division on upper scale-values is 5 mil-amperes, and each on lower scale-values .5 mil-ampere readable to .05	Revel
6	500 / 10	Do. do. with ratio of 50, each division on upper scale-values is 5 mil-amperes; each division on lower scale-values is .1 mil-ampere readable to .01	Revelry
7	500 / 10	Do. do. No. 6, with a resistance box having 2 values which, when used in connection with lower scale, reads to 10 volts by .1-volt divisions, and to 100 volts by 1-volt divisions	Revenge

Ammeters.

No.	Scale in amperes.	Single-scale divisions of an ampere, readable	No.	Scale in amperes.	Single-scale divisions of an ampere, readable
1	5	.05 ampere, to .005 do.	4	50	.5 ampere, to .05 do.
2	15	.1 do. to .01 do.	5	100	1 do. to .1 do.
3	25	.25 do. to .025 do.	6	150	2 do. to .1 do.

Telegraphic Codes.—1. Revere; 2. Revered; 3. Reversal; 4. Review; 5. Revile; 6. Revival.

Railroad Crane.

The Farrell Foundry and Machine Co., Ansonia, Conn.

Post.—Of cast iron, in one piece, fitted to deck-plate, with faced joints and secured by bolts running through a stone foundation, set up on anchor plates on its under side.

Jib.—Of two wrought-iron beams, bolted at head and foot to a bonnet and shoe, with tie bolts between them, and secured to the post by bolts which lead from its head to a yoke, which turns on a pin in the hub.

ith a pin is fitted into head of post, on which the jib turns.

s secured by two bolts, which lead down through and are secured ate on the foundation.

Double and set for both fast and slow motions, and detachable, aring load by a brake.

ane," and all sheaves have roller bushes.

Capacity.

adius.	Capacity	Weight.	Radius.	Capacity.	Weight.
Feet.	Tons.	Lbs.	Feet.	Tons.	Lbs.
15	6	10 400	16	15	17 400
15	10	14 600	20	20	23 800

or operation on Wrecking and Constructing cars.

Vacuum Pumps.

Guild & Garrison, Brooklyn, N. Y.

Vacuum Pumps.—Air pumps are so termed when they are used in connection with vacuum pans, multiple effects, or filters.

It is impracticable to define a general rule for their capacity, as the circumstances of their operation vary in different cases.

Vacuum Evaporators.—Their dimensions depend upon the temperature to which they are submitted, the evaporation, character of the liquid concentrated, vacuum desired, and type and efficiency of the condenser.

Dry Exhaustion.—When air alone is withdrawn.

$\left(\frac{V'}{V'+V}\right)^n M = Q.$ *V and V′ representing volumes of cylinder and receiver, M volume of air in receiver at commencement of operation, both in cube feet, n number of strokes of piston, and Q volume of air remaining after n strokes of piston.*

Condensation.—There are two systems in operation for vacuum pans and multiple effects, viz.—

Dry System.— Where the condenser is fitted with a leg pipe or barometric tube, through which the injected water passes off by gravitation.

Wet System.—When the pump receives and discharges the condensing water, in addition to its maintaining a vacuum.

In either system the pump is required to discharge: 1st. The air contained in the injection water, in the liquid, and in the pan, pipes, and condenser.—2d. The incondensable gases evolved from the liquid in operation.

Notes.—The Pan and its immediate connections are made of iron, copper, bronze, or alloys.

In designating the design and construction of pump required, the liquor, the volume, the degree of concentration required, and the time in which the operation must be completed, should be furnished.

To facilitate transportation, the bed plates of the large sizes are cast in two parts and bolted together.

An order for a pump should state: 1st. What liquor, and volume of it, is to be evaporated in a given period, as an hour? 2d. What the diameter of pan or evaporating vessel, and what that of vapor pipe when it enters condenser? 3d. What the heating surface of pan, and has it a steam-jacket and coils, and if coils, what is their diameter and length? 4th. If heating surface is of iron, brass, or copper? 5th. What the average temperature of condensing water, and what the volume of it?

Duplex Vacuum Pumps.

Fly-wheel Type for "Dry" or "Wet" System.

Dimensions.			Volume per Revolution.	Displacement, at 75 Feet Piston Speed per Minute.		Diameter of Pipes.		
Diameter of Vacuum Cylinders.	Diameter of Steam Cylinders.	Stroke.		Per Min.	Per Hour.	Suction and Discharge.	Steam.	Exhaust.
Ins.	Ins.	Ins.	Cub. feet.	Cub. feet.	Cub. feet.	Ins.	Ins.	Ins.
6	5	6	.589	29.45	1 767	*.* circumstances of the case.	1	1.25
8	6	6	1.047	52.35	3 141		1.25	1.5
10	7	6	1.635	81.82	4 909		1.25	2
10	8	6	1.635	81.82	4 909		1.5	2
12	8	9	2.356	117.81	7 068		1.5	2
12	9	9	2.356	117.81	7 068		1.5	2
14	9	9	3.207	160.35	9 621		1.5	2
14	10	9	3.207	160.35	9 621		1.5	[illegible]
16	10	9	4.188	209.4	12 564		1.5	
16	12	9	4.188	209.4	12 564		2	
18	12	9	5.301	265	15 898			
18	14	9	5.301	265	15 898			
20	12	9	6.545	327.25	19 635			
20	14	9	6.545	327.25	19 635			
22	14	9	7.919	395.95	23 757			
22	16	9	7.919	395.95	23 757			
24	16	9	9.424	471.25	28 275			
24	18	9	9.424	471.25	28 275			

Drawing, Tracing, Profile, Cross-Section, Pho[to-] Printing Papers and Drawing Cloths.

For Designations and Dimensions see p. 29.

In Sheets. Whatman's Hand-made.—Three styles of ma[ke] **HP.** signifies "Hot Pressed," has a smooth surface, suited for pencil and ink drawings.—**N.** signifies "Not Hot Pressed," has a finely grained surface, us[ed] general purposes and water-colors.—**R.** signifies "Rough," has a coarsely grained [sur]face, used for very bold drawing and sketching (Torchon Paper).—"Selected B[est]" and "Retree" are of like quality. "Selected Best" is free from imperfection.

In eight sizes, from 13×17 ins. to 31×53 ins. Royal, Imperial, and Double E[le]phant, also with rough surface and with all surfaces extra thick and extra he[avy].

Universal, for general drawing and water-colors, six sizes, 14×17 ins. to ... ins.—*Normal*, Not hand-made, but very similar to the Not Hot Pressed, in R[oyal], Imperial, and Double Elephant.—*Duplex*, Cream color, for fine detail and ... drawings, in Royal, Imperial, and Double Elephant.—*Duplex*, Drab Color, ... Double Elephant only.—*Bristol-Board* (Reynolds's), Five sizes, 12.5×15.25 ... 21.5×28.75 ins., 2, 3, or 4 sheets in thickness. Patent, 10×15 ins. and $15 \times$ ...

Tracing Papers.—*Vegetable* (French), Five sizes, 13×17 to 29×42 ... *Acanthus*, Very thin, 30×40 ins.—*Hermes* (common), 20×30 and 30×40 ins.—... Tough, 20×27 and 27×40 ins.—*Corona*, Thick, 27×40 ins. Of these the Veg[etable], Ceres, and Corona are natural Tracing paper (not oiled, etc.).

In Rolls.—*Duplex*, Medium, cream color, 36, 42, and 56 ins. in width.—... Thick, drab color, 36 and 56 ins. in width.—*Universal*, For general drawing, ... etc., 36, 42, 56, and 62 ins. in width.—*Anvil*, Medium and thick, surface and ap[pearance] pearance similar to Whatman's Not Hot Pressed, medium, 36, 42, and 62 in width; thick, 62 ins. in width.—*Paragon*, Pebbled surface (similar to egg-sh[ell]) thin, medium, thick, and extra thick. All 58 ins. in width, except medium, wh[ich] is also 36 and 42 ins. in width.—With smooth surface (similar to Whatman's H[P] on one side, smooth on the other), medium and thick, both 58 ins. in width. ... can be had by the yard, in 10-yard lengths or in rolls of about 35 lbs.

Detail.—*Economy*, Nearly white, thin, 50-yard rolls, 60 ins. in width.—*[Du]plex*, Medium and heavy (Manilla), 36, 42, and 54 ins. in width, in 100-yard or ... pound rolls.

Mounted.—*Universal*, *Duplex*, *Anvil*, and all the *Paragon Papers*, ... extra thick, are mounted on muslin, in all the widths, by the yard, or in ... 20 yard rolls. All the sheet papers are also to be obtained mounted.

Photo-printing Papers.—Helios Blue Print, medium and thick, pre[pared] pared (sensitized), 24 to 42 ins. in width; unprepared, 24 to 54 ins. in width. ... in sheets, five sizes. E. T. Paper, very thin, for mailing, prepared and unprep[ared], 24, 30, and 36 ins. in width. The prepared paper is in 10-yard rolls; unprepared 50-yard rolls. Blue Process Cloth, prepared and unprepared, in 10-yard ... and 42 ins. in width. Nigrosine (Positive Black Process), 10-yard rolls, 30, 36, 42 ins. in width, prepared only; Cloth, 36 and 42 ins. in width, prepared only.

Profile Paper.—In orange or green, rulings 4×20, 4×30, and ... sheets about 15×42 ins.; also continuous in 50-yard rolls or by the yard.

Cross Section Papers.—10×10, 16×16, per inch, 5×5 to the half ... and 8×8, millimeter, all in sheets about 16×20 ins. 10×10, 16×16 and m[illimeter] also continuous in rolls and in the usual variety of colors.

Ruled Cross Section, common, 5×5, 10×10, 8×8, and 4×4 per inch.

Parchment.—Medium and thick, for Blue Prints direct from drawings with[out] out tracing.

Tracing Papers.—*Parchment*, 20 yards, 37 ins. in width.—*Abe...*, thin, 40 yards, 42 ins. in width.—*Patera* and *Gothic*, very tough, 20 yards, 42 ... width.—*Doric*, medium, 20 yards, 42 ins. in width.—*Alba*, for transferring, 20 yards, 54 ins. in width.—*Lotus*, thin, 20 yards, 42 ins. in width.—*Libra*, thick, ... yards, 42 ins. in width. The Parchment, Alba, Lotus, and Libra are natural Tr[acing] Papers (not oiled, etc.). All these papers can also be obtained by the yard.

Tracing Cloths.—Excelsior, Extra fine, very thin, 30, 36, and 42 ... width.—*Imperial*, Both sides glazed or one side dull, 30, 36, and 42 ins. in wi[dth].—*Union*, Thick, for coarse tracings, 30, 37, 40, and 43 ins. in width.

Mechanical Refrigeration.

The De La Vergne Refrigerating Machine Co., New York.

Mechanical Refrigeration is effected by *Compression, Conde tion*, and *Expansion* of a liquefiable gas.

The Refrigerating or Heat-absorbing agents are Ammonia, Ether, phurous Oxide, Carbonic Acid, etc., which undergo the operations at given. The De La Vergne Machine is operated with Ammonia.

Compression.—The gaseous agent is compressed if Ammonia is to from 125 to 175 lbs. per sq. inch; during which operation heat is de oped in proportion to the pressure exerted upon the gas, or the relative ume to which it has been reduced.

Condensation.—The heat developed in the operation of compres is withdrawn from the compressed gas, which is forced through coils metal pipe, surrounded with cold water. As soon as the condition of satu tion is reached, the gas assumes a liquid state.

Expansion.—The liquefied gas is also passed through coils of m pipe, suspended or seated in a space where the substance to be cooled, as water, brine, beer, etc., is introduced; the pressure in the interior of the c being at a lower point than that required for the maintenance of the in the liquid state.

The liquefied gas, upon entering these coils, again expands, and extr from them and the substance around them the same quantity of heat t was previously given up by the gas to the water of condensation.

The gas, having passed through this routine of operation of refrigerati is now in a condition to be used in a repetition of it.

The gas is forced through these coils by the pressure in the condenser, which the use of Ammonia, is generally from 125 to 175 lbs. per sq. inch. Under pressure and the cooling action of the water, liquefaction occurs, and the result liquefied gas flows to a stop-cock, having a minute opening, by which the press in the condenser is reduced to a pressure of 10 to 30 lbs. per sq. inch in the exp sion coils, and where the liquid through reduction in pressure is again transforr into a gas. By the exhausting operation of a gas-pump, this pressure is maintair and then the gas is forced by compression into the condenser again.

Thus the expansion coils, although similar to those for condensation, are opera for the reverse, which is the absorption of heat by the liquefied gas, instead of extraction of heat from it.

In Operation, heat is transmitted from the outside through the walls of the pansion or cooling coils, and is absorbed by the expanding liquefied gas within s coils. This heat is borne by the gas through the pump into the condenser, wh it is in turn transferred to the cooling water through the walls of the conden coils, and ultimately carried away by this water.

NOTE.—Liquefied ammonia in a gaseous condition at atmospheric pressure and temperature of expands about 1000 times, and upon its expansion re-absorbs a quantity of heat equal in amount to originally held and evolved from it during liquefaction.

The liquefied gas, entering the coils through the minute opening in stop-cock immediately relieved of a pressure of 125 to 175 lbs., that requisite to maintai in a liquid state, when it boils and expands into gas. To obtain this, heat is quired, and which alone can be supplied from the substance surrounding the such as air, brine, water, etc.

As a result, the surrounding substance is reduced in temperature, the q of heat withdrawn by the gas being the same as that which was withdraw during its liquefaction in the condenser.

Consequently, if the expansion coils are set in an insulated frigerated; *and if brine or any liquid surrounds the coils, it w perature, and brine, in this* condition led into a space throug *duit, will refrigerate it.*

4 M*

Results of Operation of Refrigerating Machines of 200* Tons.

At Lion Brewery, New York. Duration of Test 11 h 20 min.

Steam Cylinders.—Diameter, 36 ins.; *Stroke of Piston*, 36 ins.——— *Pressure* of steam (mean), 48.4 lbs.

Gas Compressors.—Two double acting; diam. 18 ins.; *Stroke of Piston*, 36 ins.; back-pressure, 28.22 lbs.; condenser, 180.78 lbs. per sq. inch; *Revolutions*, 39.55 per minute.

Test for cooling made by running water of a mean temperature of 100.95° over wort, Baudelot Cooler, and cooling same to a mean temperature of 50.77°.

Refrigeration, equal to melting of 210 tons Ice per day of 24 hours.

Horse Power. — IHP = 313, and assuming consumption of coal at 3 lbs. per hour per IHP, ratio of refrigeration = 20.84 lbs. ice per lb. of coal.

If operated under ordinary condensing pressure of 156 lbs., the IHP would be 278, and ratio 23.47 lbs. ice per lb. of coal; IHP per ton of ice per day = 1.183.

Of a 20-Ton Machine. *At Bohlen-Huse Machine and Lake Ice Co., Memphis, Tenn. Duration of Operation 20 Days.*

Steam Cylinder: Diameter, 22 ins.; *Stroke of Piston*, 28 ins.; Steam, 93.49 lbs. per sq. inch.—*Gas Compressors*, Two single-acting: diam., 14 ins.; *Stroke of Piston*, 28 ins.—*Revolutions*, 40 13 per min.—*Temperatures:* Cooling water 63°, brine 18.6°; coal consumed, 180 597 lbs.; Ice produced. 1 221 172 lbs.—*Ice-making*, 26.83 tons per day of 24 hours.—*Steam-boiler* evaporated 5.5 lbs. water per lb. coal.

* All tons are given at 2240 lbs. See foot-note, p. xxvi.

FORCITE POWDER.

American Forcite Powder M'f'g Co., New York.

Forcite. — Is an improvement in Nitro-glycerine compounds, and it presents the following elements:

It is less sensitive to shock than other explosives.

Assuming Dynamite No. 1 as the Standard = 100.

Forcite No. X,	95 per cent. Nitro-glycerine,	133 per cent. intensity.
1*	75 " " "	125 " "
3†	40 " " "	95 " "

* 25 per cent. stronger than Dynamite No. 1. † Within 5 per cent. the strength of No. 1, 75 per cent.

It is more powerful than any other known explosive in our market.

See Report of Henry L. Abbott, Lieut.-Col. E. U. S. A.

It is safe in handling and transportation, quintuple force-caps being applied to explode it, and free from noxious fumes. Water-proof, free from the absorption of moisture, and is not injured by submersion in water.

Directions in Use.

In Blasting, fill the hole, and thoroughly tamp the charge.

Thaw it, if frozen, as frozen powder will not explode with its proper effect.

- or caps should be maintained dry, and are not to be stored in same the powder.

;nited by weak caps, instead of being exploded, emits noxious vapors.

nt. o glycerine in Brands of Forcite.

No. 2...... 50	No. 3...... 40	No. 3 B..... 30
" 3X.... 45	" 3 A.... 35	" 3C..... 30

der, one and a half times stronger.

SURFACE CONDENSATION.

Wheeler Condenser & Engineering Works, New York.

›nstruction.—The Wheeler Condenser, alike to others for the same ›se, is an elongated vessel, cylindrical or cubical, with the necessary at- ɑents for Steam and water connections.

distinguishing features are: The exhausted steam, upon entering the ›nser, impinges upon a perforated scattering plate, which distributes it ·ally over the tubes and thus diverts the deteriorating effect of the direct ıgement of it upon one portion of the tubes; the steam, expanding void above the tubes, is reduced in pressure, and consequent temperature, e it flows into contact with the surfaces of the tubes.

ch pair of tubes is composed of an external and internal tube, set hori- .lly, the inner tube having an open end, the other end being screwed a removable head or vertical diaphragm, which is set at a space of a nches from a like head, into which one end of this large tube is screwed, ther end being closed by a screw cap.

is design permits the tubes to expand or contract, without the use of packings or ferrules of any kind, as only one end of each tube is fixed. e tubes are tinned both externally and internally, and can be readily lrawn for cleaning, etc.

›eration.—The tubes are divided into two distinct tiers; the condens- rater flowing through the small tubes in the lower division passes out ›ir open ends and through the annular space between their external sur- and the internal surfaces of the larger tubes, and from thence into the · division, and through its tubes in like manner to the space between the .eads referred to, and finally out through the discharge pipe.

e circulation of the condensing water is by this manner of flowing ren- very active, and consequently a less volume of it is required, and there ; tube surface needed for a required volume of condensation.

ults of an Operation to Determine the Efficiency f this Condenser, with and without a Vacuum.

Steam Condensed per Hour per Sq. Foot of Condensing Surface.

›ser.	Vacuum.	Temperatures. Injection Water.	Discharge Water.	Reservoir.	Steam Condensed.	Condenser.	Temperatures. Injection Water.	Discharge Water.	Reservoir.	Steam Condensed.
	Ins.	Deg's.	Deg's.	Deg's.	Lbs.		Deg's.	Deg's.	Deg's.	Lbs.
h ım	24.5	56.5	98	138	101.8	Without Vacuum*	78.5	139	201	204.2

* As a simple surface condenser without air pump attached.

REFRIGERATING AND ICE-MAKING.

Refrigerating Machine is one that produces as low a temperature as a volume of ice, at the temperature attained, would in melting from the ›rature of the air, or void to be refrigerated = 142° (142.6°) of temper- are required to transfer one lb. ice at 32° to one lb. water at 32°, whi ence represents the Latent heat.

order to operate such a machine for the formation of ic red, instead of 142°, about 236°.

s, Assume the water from which the ice is to be formed *rature of 72°;* then to reduce it to 32°, before ice can b *l units are to* be abstracted from each lb. of water; th *d from the lb. of* water of 32° to reduce it to one lb. ice

If the ice is produced at the general temperature of 18°, and the Specific heat it is taken at .5°; then, $32-18\times.5=7°$. To reduce this water from 72° there is a reduction of 40° or thermal units from each lb. of water.

If ice is produced at 18°, Then 7° additional, as deduced above, are required.

In practice it is observed that the average loss of temperature by radiation from the freezing tank, melting the external surface of the ice, to withdraw it from the molds, etc., is fully 20 per cent. of the total capacity of the machine. Hence, of the 236° which are to be abstracted from the water per lb. of ice, in order to reduce it to ice, 47.2° are lost by radiation. And $40+142+7+47=236°$ are to be abstracted from each lb. of water of 72°, in order to produce 1 lb. ice at 18°.

Consequently, If 142° are required in Refrigerating machine and 236° in ice-making, the relative requirements are as 1 to 1.66 or as 6 to 10.

Refrigerating Capacity.—Of a machine is designated by the number of lbs., or tons of Ice, which it is capable of producing.

One lb. of ice at 32° absorbs 142° or thermal units in melting. Hence, a ton of ice absorbs $142°\times2240=318\,000°$, and a machine of 50 tons' capacity absorbs $318\,000°\times50=15\,900\,000°$ every 24 hours of its operation.

Ice-making Capacity.—Of a machine is also designated by the number of lbs., or tons of Ice, which it is capable of producing.

To freeze one lb. of water at 72° to ice at 18°, it requires the absorption of viz., To reduce one lb. of water at 72° to 32°, it requires the absorption of 40°; to freeze it requires 142°; to reduce ice from 32° to 18° requires $14\times.5=7°$ (Specific heat of ice $=.5$). Reduction of temperature from surface of freezing tank, withdrawing the ice from its molds by the application of heat, about 20% of capacity of machine $=20\%$ of $236=47°$. Hence, Total heat to be absorbed per lb. of ice $=40+142+7+47=236°$.

Ratio of Capacity of Refrigerating to Ice-making.—As 142 : 236 : : 6 : 10, as preceding, or a Refrigerating machine of 9.97 tons capacity will produce about 6 tons of ice in the same period.

Highest Elevation of a Lake.

Colorado.—"Green Lake" is 10 252 feet above level of the sea and 300 feet in depth.

Magnifying.

Bavaria, Munich, possesses a microscope that magnifies 16 000 diameters.

Power of Screw Bolts.

Results of an Experiment.

Wrought-iron.—*Diameter*, 2 ins. *Thread*, V. *Pitch*, .22 ins.

Mean Power applied at a circumference of 78.85 ins., 213 lbs.

Loss by friction, 10.19 *per cent.*

(*Jas. McBride, M. Am. Soc. E.*)

Duration of Railroad Cross-ties.

Duration of Following Woods.

Wood.	Years.	Wood.	Years.	Wood.
White Cedar	8.75	Chestnut	7.5	Yellow Pine
White Oak	8	Red Spruce	6	Hemlock
Black Cypress	8	Red Oak	5.5	Tamarack

The elements of durability are Resistance to decay and to wear. White Oak combines both qualities to the highest degree. Yellow Pine resists wear, but Red Cedar and Black Cypress resist decay, but not wear.

Ties should not be cut when the tree is in leaf, and should be well preserved by some antiseptic process before being laid.

Proper draining of a road-bed will add to the duration of ties, and all injury to their surface by tools, etc., should be avoided, and all spike-holes to avoid the absorption of water. (H. W. Reed.)

GAS AND ELECTRIC LIGHTING.

(*In Addition to pp.* 583-587). **Gas.**

...le Power and Consumption of Different Burners.

...Burner.	Candle Power. No.	Candle Power. Per Foot per Hour.	Consumption per Hour per Lamp.	Burner.		Candle Power. No.	Candle Power. Per Foot per Hour.	Consumption per Hour per Lamp.
		No.	Feet.				No.	Feet.
...g......	10	2.33	4.3	Flat Flame	In Clusters.	60	4	15
from..	11.5	2.5	4.6			90	5.5	20
to.....	13.8	3	4.8			150	5	30

Electric.

Arc Lamps.

...	Candle Power. Horiz'tal.	Angle 7°.	Angle 10°.	Angle 20°.	Angle 40°.	Watts Required.	Units per Hour.	Relative Costs* of Gas. Electric=1.
	No.	No.	No.	No.	No.	No.	Hour.	
	92	175	207	322	460	300	.3	2.67
	156	300	350	546	780	400	.4	3.77
	220	420	495	770	1100	500	.5	4.83

* Per Candle Power for Batswing Burner.

...hts should be set high and for the following causes:
...eir high candle power and distance apart being in excess of gaslights.
...ht radiating at a depressed angle is greater than when cast horizontally.
...zontal rays are not as steady as angular.
...e greatest intensity with continuous currents is at an angle of 40° be-
...ntal line.

...rmine the Coefficient of Minimum Lighting Power in Streets.

= Co. L *representing candle power of lamps.* D *maximum distance* ...d H *height of lamp, both in feet, and* Co, *coefficient.*

...ard for Gaslighting is assumed for a unit of pavement 50 feet dis-
...p of 12 candle power 9 feet in height. Hence,

$$12 \times 9 \div 50^2 = .000\,864.$$

...is coefficient, the following capacities of arc lights will give the same
...ht at the following height and distance.
...standard would increase the coefficient to .001 728.
...arc light can replace from 3 to 6 gas-lamps, according to locality and
...ht adopted.
...ting, based on the substitution of one light for 3.5 to 4 gas-lamps,
...he minimum standard of light; while the average standard would
...m 10 to 12 times.

(*Eliminated, etc., from Papers of Henry Robinson, M.I.C.E.*)

Railroad Speed.

N. Y. Central and Hudson River R. R.—...
Buffalo, N. Y. 436 miles in 426 minutes, a...
...hour. *Weight of Train* 230 tons.
..., Fairport, 361 miles in 360 minutes, there de...
...phia and Reading R. R.—One mile in 39.7...
...ur.
...an, " London to Edinburgh, 400 miles;
= 47.05 *miles per hour.*
...xcluding locomotive, 80 tons.

Tenacity of Round and Square Wrought-Iron Bol Holes of Different Diameters.

Round.—.75-inch, driven into a hole of .625 inch, in White Pine, for 12 required 6875 lbs. to withdraw it.

1-inch, driven into a hole of .75 inch, in White Pine, for 12 ins., required lbs. to withdraw it; and in Norway Yellow Pine. 10 830 lbs.

1-inch, screwed, 8-threads per inch into a hole .8125 inch, in White Pine, for required 15 125 lbs. to withdraw it, and one of 12 threads required 15 250 lbs.

1.125-ins., driven into a hole of .875 inch, in Hemlock, for 12 ins., requir lbs. to withdraw it.

Square.—The difference between that and Round, under like conditio essentially different, and when a hole was bored 10 ins. in depth, the differe not essential.

Railway Spikes.

Length in Tie.	To Withdraw					Remarks.
	Chestnut.	Y. Pine.	W. Cedar.	W. Oak.	Hemlock.	
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
4.6	3264	3198	2305	4330	3485	In solid wood, sharp po

Ship Spikes.—.375 inch square and 7 ins. in depth, driven 3 ins. in Pine and drawn back, required 1617 lbs., their edge with the grain of the woo 1317 lbs. with it across.

Note.—The above are deduced from Experiments of Gen. Weitzel, U. S. 1874–77.

Resistance of Bolts, after being 7 months driven = 10 per cent. greater th mediately after, and when driven through in direction of fibre it is but 6 cent. of that of being withdrawn.

Smooth bolts have greater retention than ragged, either driven or withdraw

Moderate "ragging" reduces their power 25 per cent., and extreme 50 per c

Relation between diameters of bolt and hole showed that the resistance of a of 1 inch in a .6875-inch hole was greater than in one of .75 or .8125 inch.

With a .75-inch bolt the resistance was greater in a hole of .625 inch, and one quarter greater than in one of a sixteenth greater or less.

One-inch square bolt in a .875-inch hole was the same as a round bolt in a .6 inch hole.

Screw-bolts are about 50 per cent. more effective than plain round.

Long pointed blunt bolts are more effective than short pointed.

Experiments of Mr. F. Collingwood and Wm. H. Paine, made in connection construction of the New York and Brooklyn Bridge, gave for a 1-inch round driven in a .9375-inch hole, in best Georgia Pine, a resistance of 15 000 lbs. per li bot, and in a .875-inch hole 12 000 lbs. In lighter woods the tenacity was less.

Mr. J. B. Tscharner, in the laboratory of the University of Illinois. deter like bolt (1-inch round), under like conditions in White Pine, was 6000 at a bolt driven parallel to the grain of the wood has but half of the re that driven perpendicular to it. Further, that assuming a bolt of 1 inc as 1, that if driven in a .75-inch hole it would be 1.69, and in a .8 13.

Driving Resistance of Round and Squa Steel Bolts.

Diameter. Drive into *Pine Wood.* *Six Inches in Depth.*

	Square.			Round.	
1	.9375	.875	.8125	.9375	.875
[illegible]	4260	4660	4050	2250	3798
2	710	777	675	375	6[illegible]

(J. H. Powell and A. F

of metal in the Round bolts is the least expensive.

Mortar.

large to a ...

preferable.

air Mortar.—

Large Trees in Australia.

Victoria. Eucalyptus —

Speed of Vessels.

To Determine the True Speed of a Vessel ... and Alternate Runs over a Measured Distance.

Miles or Knots.	Ist Results.			
15.6				
	12.9			
10.2		12.6		
	12.3		12.55	
14.4		12.5		[illegible]
	12.7		12.45	
11		[illegible]		[illegible]
	12.1		[illegible]	
13.2		12.3		
	12.5			
11.8				
	62.5 ÷ 5 = 12.5			

Note.—The mean of ...

Velocity of the Current.

To Determine the Velocity of the Current and ... the Vessel's Course.

From the observed speed of the vessel ... the velocity of the current.

Illustration.—Assume preceding runs

Runs.	Speed. Observed.	True	
1	15.6		
2	10.2		
3	14.4	12.45	
4	11		
5	13.2		
6	11.8		

Relative Corrosion of Wrought Iron

In Air.................... 1.

In contact with brass................ 3.4 | In contact with lead

" copper.............. 4.0 | " " gun.

In contact with tin.............. 8.7.

PILE-DRIVING.

(*Continued from page 672.*)

To Compute Weight of Ram. (*Molesworth.*)

$P\left(\frac{hP}{5AL}-1\right)=R$. P *representing weight of pile in lbs., h height of fall of ram, and L length of pile, both in feet, and A area of section of pile in sq. ins.*

Piles are distinguished according to their position and purpose: the *Gauge Piles* are driven to define limit of area to be enclosed, or as guides to the permanent piling.

Sheet or *Close Piles* are driven between gauge piles to form a compact and continuous enclosure of the work, and are driven as close and uniform to each other as practicable of attainment, and the intervening space or joint, however close, is made water-tight by the introduction of a "feather" driven in a groove on the sides of the piles.

Crushing.—Crushing resistance of a pile, unless of very hard wood, should not be estimated to exceed a range of from 500 to 1000 lbs. per sq. inch.

Refusal of a pile intended to support a weight of 13.5 tons can be safely taken with a ram of 1350 lbs., falling 12 feet, and depressing the pile .8 of an inch at final stroke.

Pneumatic Piles.—A hollow pile of cast iron, 2.5 feet in diameter, was depressed into the Goodwin Sands 33 feet 7 ins. in 5.5 hours.

Water Jets.—A stream of water is ejected under pressure at the point of a pile, and, rising around it, removes the end and surface resistance, so that it will be more easily driven. Suited for sand or fine soil.

Nasmyth's Steam Pile-hammer has driven a pile 14 ins. square, and 18 feet in length, 15 feet into a coarse ground, imbedded in a strong clay, in 17 seconds, with 20 blows of ram, making 70 strokes per minute.

Shaw's Gunpowder Pile-driver is operated by cartridges of powder on head of pile, which are ignited by fall of the ram. 30 to 40 blows per minute have been made under a fall of 5 and 10 feet.

Sheet Piling.

Bevelling.................... 120° | Shoeing....................... 25°

To Compute Coefficient of Resistance of the Earth.

$\frac{Rh}{d}=C$. R *representing resistance of the earth, h height of fall of ram, and d final depression, both in feet.*

Ringing Engine

Requires 1 man to each 40 lbs. of ram, which varies from 450 to 900 lbs.

To Color Brass (Copper and Zinc) Blue.

Mix in a close vessel 100 grains = 6.5 oz. Troy, of Carbonate of Copper and 750 grains = 4.06 lbs. Troy, of Ammonia; shake until solution is effected and then add distilled water; shake, and the solution is ready for use.

Keep it cool and effectively stopped. If deteriorated, add a little Ammonia.

Articles to be colored, to be perfectly clean, suspended in motion in the solution; remove there[illegible] in from 2 to 3 minutes, wash in pure water, and dry in sawdust or like e[illegible]rial.

Expo[illegible]eration as little to the air as practicable.

Oth[illegible]er and tin and argentine, [illegible] available.

(Chemical Jo[illegible]

STEEL SPRINGS. *(Additional to page 779.)*

To Compute Safe Elements of Springs.*

$$\frac{}{n}=D; \quad \sqrt[3]{\frac{D\,b\,t^3\,n}{.8}}=l; \quad \frac{.8\,l^3}{D\,t^3\,n}=b; \quad \sqrt[3]{\frac{.8\,l^3}{D\,b\,n}}=t; \quad \frac{.8\,l^3}{D\,b\,t^3}=n; \quad \frac{b\,t^2\,n}{5\,l}=L.$$

representing deflection and t thickness of plates, both in 16ths of an inch; l length ɔan or bearings when weighted, and b breadth of plates of springs, both in ins.; mber of plates, and L load or stress in 1000 lbs.

ᴛᴇ.—The plates are assumed to be similar and regularly formed.

ᴜsᴛʀᴀᴛɪᴏɴ.—Assume a spring of the following elements:

$l=20$ *and* $b=3$ *ins.*, $t=4$ 16*ths*, $n=5$, *and* L 2400 *lbs.*

$$\frac{.8\times 20^3}{\times 4^3\times 5}=\frac{6400}{960}=6.66\ 16ths; \quad \sqrt[3]{\frac{6.66\times 3\times 4^3\times 5}{.8}}=\sqrt[3]{\frac{6400}{.8}}=20\ ins.;$$

$$\sqrt[3]{\frac{.8\times 20^3}{6.66\times 3\times 5}}=\sqrt[3]{\frac{6400}{100}}=4\ 16ths; \quad \frac{.8\times 20^3}{6.66\times 3\times 4^3}=\frac{6400}{1280}=5;$$

$$\frac{.8\times 20^3}{6.66\times 4^3\times 5}=\frac{6400}{2133}=3+ins.; \quad \frac{3\times 4^2\times 5}{5\times 20}=\frac{240}{100}=2.4\ 1000\ lbs.$$

ɔᴛᴇ.—When back or short plates are added, they are to be added to the number ates if of the ruling breadth and thickness.

hen extra thick back or short plates are added, they are to be represented by ɜs of ruling thickness having an equivalent resistance, prior to computation by ıulas for D and L, and are thus ascertained: multiply number of additional ɜs by cube of their thickness, and divide product by cube of ruling thickness.

ʟᴜsᴛʀᴀᴛɪᴏɴ.—Assume as preceding, thickness of plates $=4$ 16ths, number of ı 5, and 3 extra plates of 5 16ths to be added.

.en, $\frac{3\times 5^3}{4^3}=\frac{375}{64}=5.86=$ *no. of plates, and* $5+5.86=10.86$, *the no. of plates* 16*ths in thickness.* $10.86\times 4^3=695$, and $\left.\begin{array}{l}5\times 4^3=320\\ 3\times 5^3=375\end{array}\right\}695.$

ɜnce, 3 *plates of* 5 16*ths added to the* 5 *of* 4 16*ths* $=10.86$ *plates of* 4 16*ths.*

nversely, $695\div 5^3=5.56$ *plates of* 5 16*ths are equal to the* 10.86 *of* 4 16*ths.*

Helical Steel Springs.

$$\frac{d^3\,L}{C\,t^4}=D; \quad \sqrt[4]{\frac{d^3\,L\,D}{C}}=t; \quad \sqrt[3]{\frac{C\,t^4\,D}{L}}=d; \quad \frac{C\,t^4\,D}{d^3}=L.$$

addition of .125 to .25 should be added to the diameter or square to compensate for a set of the ;s.

Safe Load. $\sqrt[3]{\frac{L\,d}{3}}=t$ *for round, and* $\sqrt[3]{\frac{L\,d}{3.8}}=t$ *for square.*

representing diameter or distance between the centres of the rod or bar of the ıg, and D compression of the spring, both in ins.; L load or stress applied in lbs.; meter of rod or side of square of bar in 16ths of an inch, and C a coefficient $=22$ *·ound rods and* 30 *for square bars.*

ᴜsᴛʀᴀᴛɪᴏɴ.—Assume as follows: $d=7$ *ins. square;* $L=3363$ *lbs.;* $t=16$ *six- hs, and* $C=22$.

$$\frac{\times 3363}{\times 16^4}=\frac{1\,153\,434}{1\,441\,792}=.8\ inch; \quad \sqrt[4]{\frac{7^3\times 3363\times .8}{22}} \quad \ldots 92 = 16\ 16ths;$$

$$\frac{22\times 16^4\times .8}{3363}=\sqrt[3]{\frac{1\,153\,434}{3363}}=7\ ins.; \quad \frac{22\times 16}{7} \quad = 3363\ lbs.;$$

$$\sqrt[3]{\frac{3363\times 7}{3}}=\sqrt[3]{\frac{23\,541}{3.8}}=18.$$

· *load and deflection obtained for one* coil *s* *ɜr of coils for the respective* total load and de. *ıare spring is* approximately equal to a roun

* Essentially from D. K. Clark's

Blast Draught in Ashpit of a Marine Boi

S. S. "Resolute."

IHP		Coal		Water	Re
Of Blower Engine.	Of Engine.	Per IHP per hour.	Consumed per hour.	Evaporated per lb. of Coal.	Eff
No.	No.	Lbs.	Lbs.	Lbs.	Pe
Natural Draught ..	57.5	3.72	214	10.77	1
.96	88.8	3.26	290	8.82	1
2	100.5	3.12	314	8	:
3	106.1	2.04	323	7.82	:
4.2	118.8	2.93	348	7.82	
5	119.8	3.12	374	7.53	
6	127.9	3.12	399	7	
7.4	135.7	3.1	421	7.03	

When the Power was Doubled.—The fuel consumed was as 1.5 to 1, tl evaporated as .73 to 1, and the saving of coal was 19 per cent.

An average of the above results gave a saving of 15.8 per cent.

By trials in the R. N., it was ascertained that a blast draught increased tl of the engines 52.5 per cent., and the boilers 65 per cent. per ton of their w

First Steam-Launch.

"SWEETHEART."—Was built at the Navy Yard, New York, in 1837.

Length, 35 feet; beam, 4.25; depth, 1.83.

Engine, vertical cylinder beam, 4 ins. in diam. by 12 ins. stroke of piston

Water-wheels, 4 feet by 10 ins. *Boiler*, horizontal fire tubular.

On her trial trip she was saluted by steamboats and assemblages of p ferryboats and on the piers. Designed by and constructed under the dire the Author.

Bearings without Lubricants.

Graphite or *Plumbago*—Is the essential element in dry bearings.

"*Fibre graphite*"—Consisting of finely-powdered plumbago mixed wit wood fibre, is pressed in a mold of the required form, then saturated with oil and oxidized in a hot dry air.

NOTE.—This bearing* has been favorably reported on by a committee of the Franklin Instit

"*Carboid*"—Is carbon mixed with finely-powdered steatite; its specific = 1.66, that of carbon being 1.48. It can be molded, turned, bored, and sh any form.

NOTE.—The coefficient of friction with dry bearings is lower than that of r bearings in good condition.

Tests for Water.

(*Additional to page* 852.)

To Ascertain

If Hard or Soft.—Into a clean glass tube put a solution of soap, add a sı ume of the water, when, if hard, the mixture will become milky.

If Alkaline.—It will turn red litmus-paper blue.

If Acid.—It will turn blue litmus-paper red.

If Carbonic Acid is present.—Equal volumes of it and lime-water will milky. Add a little hydrochloric acid to the mixture and it will become c

If Sulphate of Lime (Gypsum) is present.—Add to it a little chloride of white precipitate is formed, which will not dissolve when a small v acid is added, it contains the sulphate.

Anchoring Bolts in Stone.

st of the relative value of Lead, Sulphur, and Portland Cement, f ı of iron bolts in limestone rock, give similar results.

* Philip H. Holmes patent.

Gate Valves.

Eddy Valve Co., Waterford, N. Y.

Gate Valves, Double Seated, have faces set at a slight angle to line of stem, and as the gates, in consequence of their angular faces, cannot fill the space between the valve-seats until they are fully down to their position, the adhesion of them to the valves in their progress down, from the interposition of sediment or other obstructions, is not only not arrested, but they are impracticable of arrest before being fully seated, and left partially open, under the impression on the part of the operator that they are in position and the flow of the fluid arrested.

The valves are attached to the stem by an articulated ball joint, hence they are rendered free to revolve, and their faces varying with that of their valve-seats, cutting or grooving is measurably avoided.

The valves are two independent pieces, whereby a single defect involves the repair or removal of but one of them.

The stem rotates in a screw-collar connected to the ball joint, and hence it is not elongated outside its glands upon the raising of the valves.

lasses 1 and 6. Measurement. End to nd of crew ocket.	Face to Face of Flange.	Diameter of Standard Flange.	*Class 2.* Size.	Measurement. End to End of Screw Socket.	Face to Face of Flange.	Diameter of Standard Flange.	*Class 2.* Size.	Measurement. Face to Face of Flange.	Diameter of Standard Flange.	*Class. 3 & 4.* Size.	Measurement from End to End of Hub.
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
·375	2.5	3	2	5.5	5.75	6	14	15	21	4	12
·75	3	4.5	2.5	6	6.5	7	15	15	22	5	12.5
.875	3.25	4.75	3	7.25	7.75	8	16	16.25	23	6	13.5
·375	3.5	5	3.5	7.5	7.75	8.5	18	16.25	25	8	14.5
·5	4	5.25	4	8	7.75	9	20	17.75	27	10	15.5
·375	4.625	5.75	4.5	8.5	8.5	9.5	24	20	31	12	16
·125	5.5	6	5	9	9.25	10	30	22.5	38	14	17.25
·375	5.875	6.5	6	10.25	9.75	11	36	25.75	45	16	17.5
	6.25	7.25	7	11	11	12				18	18
.625	7	8	8	11	11	13	*Classes 3 and 4.*			20	18
·25	7.5	9.5	0	13.25	12	16	Ins.	Ins.		24	23
·75	7.75	11	2	14.75	13.5	18	2	7.75	—	30	25
—	—	—	—	—	—	—	3	10.5	—	36	30

Class.

ll Brass, Screw and Flange Ends. | 2. Iron Body, Brass Mounted. [Mains.
ub Valves, all Iron, for Gas Mains. | 4. Hub Valves, Brass Mounted, for Water
uick Opening Valves, with Rack and Pinion Stem, Iron Body, Brass Mounted.
uick Opening Valves, Rack and Pinion Stem, all Brass, Screw Ends.

Eddy Hydrants.

Eddy Valve Co., Waterford, N. Y.

n-.	Diameters of Stand Pipe.	Seat Ring.	Nozzles. 2.5 Ins.	2.5 Ins.	2.5 Ins.	2.5 Ins.	2.5 Ins.	Steamer.	Steamer and 2.5 Ins.	2.5 Ins.
	Ins.	Ins.	No.	No.	No.	No.	No.	No.	No.	No.
	4.5	3	1	—	—	—	—	—	—	—
	5.5	4	1	2	3	—	—	1	1	2
	5.5	4	1	2	3	—	—	1	1	2
	6	4.5	—	2	3	—	—	1		
	6.625	5	—	2	3	4	—			
	7.625	6	—	2	3	4	—			
	7.625	6	—	2	3	4	—			
	9.75	8	—	—	—	—	6			

ard Length from Pavement to bottom of Main or branch

Aluminum.

(*Continued from page* 938.)

The available properties of Aluminum are its relative lightness, freed tarnish, not being affected by sulphurous fumes and being slowly oxid moist atmosphere, its extreme malleability, its facility of being cast, its h fic heat and electrical and heat conductivity, and its extreme ductility.

Its transverse and torsional resistances are very low, its maximum sh sistance for castings 12 000 lbs., and forgings 16 000 lbs. per square inch.

It is adapted for structures under water, can be welded by electricit nealed if heated and gradually cooled just below a red heat. The tensile of its wire is greater than that of its rolled metal.

Its properties are materially changed and impaired by alloying it with centages of other metals, and its tensile resistance, relative to its wei plates as strong as steel at 80 000 lbs. per square inch, and in cold draw strong as it is at 180 000 lbs. (*Alfred E. Hunt.*)

Magnesium.

Specific gravity 1.74, is .33 lighter than Aluminium; is harder, te denser; less affected by alkalies, and takes a higher polish.

Staff.

Staff is composed of Plaster of Paris, water, and hemp fibre, the latt bind the mass.

For ornamental pieces, matrices of hardened gelatine are used.

It resists the weather and even frost after being saturated.

Boiler Setting.

The fire-brick should be laid with very thin joints, and set in Kaolin pared fire-clay, so thin that it is necessary to lay it with a spoon ins trowel.

Every fifth course should be a header course. ("*The Locomotive.*")

Glue.—Its tenacity varies from 500 to 700 lbs. per square inch.

Friction of Engines and Gearing.

(*In addition to pages* 469–478, *etc.*)

Deduced from Experiments of Alfred Saxton, Manchester Assn. of En

Spur Gearing	25.9 per cent.	Belt Driving	28.6
Rope Driving	29.6 "	Direct Acting	23.8

Engines............6 and 10.3 per cent.

Spur gearing gave the best result when not complicated with rope drivi

Rope driving gave best results at high speeds.

Belt driving for developing large power is only equal to an average ro engine.

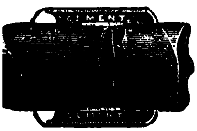
* A variety of clay, one of the two ingredients in Oriental porcelain; the other is term *petunse.*

Spirally Riveted Iron or Steel Pipe.

Abendroth & Root Mfg. Co., New York.

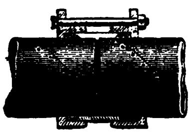
Spirally Riveted Metal Pipe,

Compared with Wrought or Cast iron Pipe, has the advantage of low original cost and expense of transportation, maintaining a nearly equal bursting pressure with that made of heavier material. It is made of Sheet Iron or Sheet Steel, varying in thickness from No. 20 to No. 12 B.W.G., according to diameter and pressure. The rivets in the seam are set by compression, while the laps are thoroughly coated with hydraulic cement to make it water tight.



Connections.—When a moderate pressure is maintained, these pipes, their ends being crimped, are usually connected by a cement joint, as shown in the annexed cut.

When the pressure is excessive, a bolted joint is resorted to, as also shown, and which is in effect a stuffing box or sleeve joint, dispensing with lead calking, and admitting of a slight flexure of the pipe.



For service connections the collar may be tapped. When lead calking is required, the inner ends of the pipe are reinforced by an iron collar.

Bursting Pressure.

Diameter Internal.	Per Sq. Inch.	Diameter Internal.	Per Sq. Inch.	Diameter Internal.	Per Sq. Inch.	Diameter Internal.	Per Sq. Inch.	Diameter Internal.	Per Sq. Inch.
Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
3	900 to 1300	6	350 to 800	10	275 to 650	16	190 to 400	22	125 to 300
4	700 " 1000	8	350 " 825	12	225 " 550	18	150 " 375	24	110 " 275
5	550 " 800	9	300 " 750	14	200 " 470	20	140 " 325	—	—

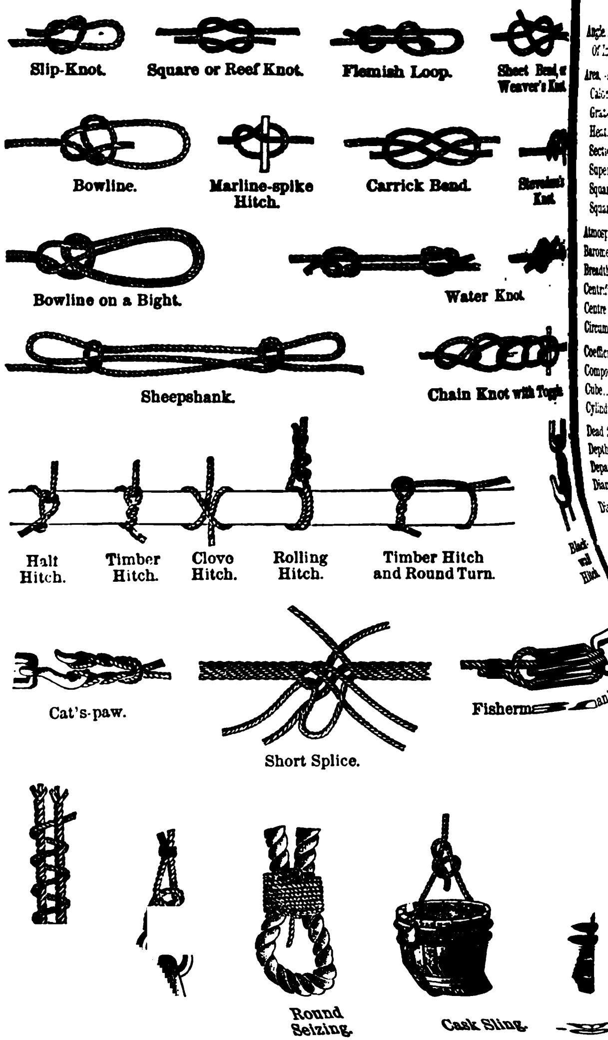
In order to enable an estimate of the relative cost of these pipes, compared with cast and ordinary wrought-iron pipes, the weights of each are submitted.

Weights.

Heavy Spiral.				Heavy Spiral.				Heavy Spiral.				Heavy Spiral.			
Diam.	Weight.	Wrought Iron.*	Cast Iron.†	Diam.	Weight.	Wrought Iron.*	Cast Iron.†	Diam.	Weight.	Wrought Iron.*	Cast Iron.†	Diam.	Weight.	Wrought Iron.*	Cast Iron.†
Ins.	Lbs.	Lbs.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.
3	2	7.5	13	8	8	28	40	14	[illegible]	[illegible]	[illegible]	20	28	—	180
4	2.5	10.75	20	10	10	40	55	16	[illegible]	[illegible]	[illegible]	[illegible]	31	—	200
6	5	18.75	30	12	13	49	70	18	[illegible]	[illegible]	[illegible]	[illegible]	33	—	250

* Standard.

In Mechanical and Engineering Operations.



SYMBOLS

[E]lements and Formulæ, proposed by the Author.

For the purpose of inducing a uniformity in their expression (1891).

....
idence......... z
.... A . a . a'
meter....... Cal.
.... Gt
[i]g surface..... Hs
[n].. Scn, H, L or T
[f]icial........ Sup.
.... Sq. or □
[Square] foot, feet... □ft.
[Amp]ere, -s....... At.
[Elect]ric........... Bc
-s......... b . b'
[Centrifu]gal force...... Cf
[Center o]f gravity...... Cg
[Circumf]erence, -s.. C.c.c'
[Coefficie]nt or Factor.. Co.
[Compoun]d.......... Cpd
.... Cub. or ⊠
[Cylindri]cal.......... Cyl.
.... ⊠
.... dp . dp'
[Depth]e........... Dpt
-s.... D . d . d,'
Inch, -es. ins.
.... ft.
s........... Yds
-s.......... Chn
s. .... Rd
s. .... K
.... Ms
[Millime]ter, -s...... mm
[Centim]eter, -s...... cm
[Decim]eter, -s...... dm
-s........... m
[Dekam]eter, -s...... dk
[Hektom]eter, -s..... hk
[Kilome]ter, -s........ kl
[Myriam]eter, -s..... mr
[Centare] or sq. meter, -s Ce
.... Ae
-s......... He
[o]f water..... Dw
-s.......... El
.... E
, U. S. or } Eq.
Ampere, -s. Am
-s. (Greek cap. phi) Φ
rad, -s (Greek phi) φ

Henry, -s........... H
Joule, -s............. J
Kilojoule, -s........ Kj
Watt, -s............ wt
Kilowatt, -s....... kwt
Millihenry, -s...... mh
Milliampere, -s..... ma
Megohm (Greek c. omega) Ω
Microvolt, -s....... Mv
Ohm, -s.. (Greek omega) ω
Volt, -s............ Vo

Evaporation, -ive.... Evp
Foot-pound, -s, tons Fp.Ft
Force................. F
Friction.............. Fn
Gravity................ *g*
Height, -s...... H . h . h'
Horse-power.......... HP
Effective.......... EHP
Indicated.......... IHP
Nominal.......... NHP
Inclination............ In
Joule's Equivalent..... JE
Latitude............ Lat.
Length, -s........ L . l . l'
Logarithm.......... Log.
Hyperbolic... Hyp. log.
Longitude...........Lon.
Mercurial gauge...... Mg
Meridian............. M
Modulus of Elasticity . ME
Moment, -s........... Mt
Number, -s........... No
Ordinate, -s..... O . o . o'
Perpendicular......... Pr
Pitch, -s......... Ph . Ph'
Pressure, -s..... P . p . p'
Quadruple........... Qpl
Radius, -ii....... R . r . r'
Revolution, -s.. Rev. rev.
Secant.............. Sec.
Cosecant.......... Cosec.
Sine................ Sin.
Cosine........... Cosin.
Slip.................. Sp
Solid................. Sd
Specific gravity....... Sg
Span................. Sn
Stability............. St
Steam.............. Stm
Stroke............ S . s

$\pi = 3.1416$

Sum, -s............... Sm
Tangent............ Tan.
Cotangent......... Cotan.
Thrust................ Tt
Time, -s......... T . t . t'
Second, -s. Sec. sec. or ″
Minute, -s Min. min. or ′
Degree, -s.... Deg. or °
Hour, -s....... Ho . ho
Day, -s............. Ds
Month, -s.......... Mo
Year, -s............ Ys
Triangle, -s......... Δ Δ'
Triple............... Tpl
Unit, -s. Heat....... Hu
Calorific or French.. Cc
Vacuum............ Vm
Velocity........ V . v . v'
Versed sine......... v-sin
Vertical.............. Vt
Volume, -s...... Vol. vol.
Chaldron, -s........ Ch
Chord, -s........... Co
Bushel, -s........... Bl
Cube foot, feet...... Cf
Barrel, -s.......... bbl
Gallon, -s........... gl
Microliter (Greek lambda) λ
Milliliter, -s........ ml
Centiliter, -s......... cl
Deciliter, -s......... dl
Liter, -s............. lr
Dekaliter, -s........ dr
Hektoliter, -s....... hr
Kiloliter or Stere, -s. Kr
Water-line............ Wl
Weight, -s..... W . w . w'
Ounce, -s........... oz
Pound, -s...... lb. . lbs.
Ton, -s (2240)..... Tons
" (2000)... —Tons
Milligram, -s....... mg
Centigram, -s....... cg
Decigr[am] ... d[g]
Grar[n]
Dek
Hek
Kilc
Myr
Qui
Mill

ORTHOGRAPHY OF TECHNICAL WORDS AND TERMS.

Orthography in ordinary use of following words and terms is so varied, that they are here given for the purpose of aiding in the establishment of a uniformity of expression.

Abut. To meet, to adjoin to at the end, to border upon. *Abut end* of a log, etc., is that having the greatest diameter or side.

But and *Butt end*, when applied in this manner, are corruptions.

Adit. In *Mining*, the opening into a mine.

Amidships. The middle or centre of a vessel, either fore and aft or athwartships. The amidship frame of a vessel is at ⊠, and is termed *dead flat.*

Arabesque. Applied to painted and carved or sculptured ornaments of imaginary foliage and animals, in which there are no perfect figures of either. Synonymous with *Moresque.*

Arbor. The principal axis or spindle of a machine of revolution.

Arris. A term in *Mechanics*, the line in which the two straight or curved surfaces of a body, forming an exterior angle, meet each other. The edges of a body, as a brick, are arrises.

Ashlar. In *Masonry*, stones roughly squared, or when faced.

Athwart. Across, from side to side, transverse, across the line of a vessel's course.

Athwartships, reaching across a vessel, from side to side.

Bagasse. Sugar-cane in its crushed state, as delivered from the rollers of a mill.

Baik. In *Carpentry*, a piece of timber from 4 to 10 ins. square.

Baluster. A small column or pilaster; a collection of them, joined by a rail, forms a *balustrade.*

Banister is a corruption of balustrade.

Bark. A ship without a mizzen-topsail, and formerly a small ship.

Bateau. A light boat, with great length proportionate to its beam, and wider at its centre than at its ends.

Batten. In *Carpentry*, a piece of wood from 1 to 2.5 ins. thick, and from 1 to 7 ins. in breadth. When less than 6 feet in length, it is termed a deal-end.

Berme. In *Fortifications* and *Engineering*, a space of ground between a rampart and a moat or fosse, to arrest the ruins of a rampart. The level top of the embankment of a canal, opposite to and alike to the towpath.

Bevel. A term for a plane having any other angle than 45° or 90°.

Binnacle. The case in which the compass, or compasses (when two are used), is set on board of a vessel.

Bit. The part of a bridle which is put into an animal's mouth. In *Carpentry*, a boring instrument.

Bitter End. The inboard end of a vessel's cable abaft the bitts.

Bitts. A vertical frame upon a deck of a vessel, around or upon which is secured cables, hawsers, sheets, etc.

Bogie. Pivoted truck, to ease the running of an engine or car around a curve.

Boomkin. A short spar projecting from the bow or quarter of a vessel, to extend the tack of a sail to windward.

Bowlder. A stone rounded by natural attrition; a rounded mass of rock transported from its original bed.

Breast-summer. A lintel beam in the exterior wall of a building.

Buhr-stone. A stone which is nearly pure silex, full of pores and cavities, and [illegible]d for Mills.

[illegible]*ng.* Woolen texture of which colors and flags are made.

[illegible] A load. The quantity that a ship will carry. Hence burdensome.

[illegible]mall cask, differing from a barrel only in size. Commonly written [illegible]

ber. An instrument with semi-circular legs, to measure diameters of spheres, [ext]erior and interior diameters of cylinders, bores, etc.

[…] of Calibers is superfluous and improper.

[…]. To stop seams and pay them with pitch, etc. To point an iron shoe so as [to pre]vent its slipping.

[…]. An irregular curved instrument, having its axis eccentric to the shaft [w]hich it is fixed.

[Cam]ber. To camber is to cut a beam or mold a structure archwise, as deck- of a vessel.

[Cam]boose. The stove or range in which the cooking in a vessel is effected. The [cookin]g-room of a vessel; this term is usually confined to merchant vessels; in [ship]s of war it is termed *Galley*.

[Cam]el. In *Engineering*, a decked vessel, having great stability, designed for use [in the] lifting of sunken vessels or structures. Also to transport loads of great [weigh]t or bulk.

[Sc]ow is open decked.

[Can]tle. A fragment; a piece; the raised portion of the hind part of a saddle.

[Can]tline. The space between the sides of two casks stowed aside of each other. [When] a cask is laid in the cantline of two others, it is said to be stowed *bilge and* [*cantli*]*ne.*

[Cap]stan. A vertical windlass.

[Car]avel. A small vessel (of 25 or 30 tons' burden) used upon the coast of France [in he]rring fisheries.

[Car]lings. Pieces of timber set fore and aft from the deck beams of a vessel, to [receiv]e the ends of the ledges in framing a deck.

[Car]vel built.—A term applied to the manner of construction of small boats, to [signif]y that the edges of their bottom planks are laid to each other like to the man[ner of] planking vessels. Opposed to the term *Clincher.*

[Cas]ter. A small phial or bottle for the table. *Casters.* Small wheels placed [on] the legs of tables, etc., to allow them to be moved with facility.

[Cat]amaran. A small raft of logs, usually consisting of three, the centre one be[ing lo]nger and wider than the others, and designed for use in an open roadstead [or u]pon a sea-coast.

[Cha]mfer. A slope, groove, or small gutter cut in wood, metal, or stone.

[Cha]pelling. Wearing a ship around without bracing her fore yards.

[Chi]mney. The flue of a fireplace or furnace, constructed of masonry in houses [and fu]rnaces, and of metal, as in a steam boiler. See *Pipe.*

[Chi]nse. *To chinse* is to calk slightly with a knife or chisel.

[Chu]ck. In *Naval Architecture*, small pieces of wood used to make good any de[fi]cy in a piece of timber, frame, etc. See *Furrings.*

[Chu]ke. To stop, to obstruct, to block up, to hinder, etc.

[Clea]ts. Pieces of wood or metal of various shapes, according to their uses, either [to bel]ay ropes upon, to resist or support weights or strains, as *sheet*, *shoar*, *beam* […], etc.

[Cli]ncher built. A term applied to the construction of vessels' bottoms, when [the lo]wer edges of the planks overlay the next under them.

[Coa]k. A cylinder, cube, or triangle of hard wood let into the ends or faces of two [piece]s of timber to be secured together. The metallic eyes in a sheave through [whic]h the pin runs. In *Naval Architecture*, the oblong ridges banded on the masts [of shi]ps.

[Coa]mings. Raised borders around the edges of hatches.

[Cob]le. A small fishing-boat.

[Coc]oon. The case which certain insects make for a covering [during thei]r metamorphosis to the *pupa* state.

Cog. In *Mechanics*, a short piece of wood or other material let into the face of a body to impart motion to another. A term applied to a tooth in a wheel when it is made of a different material than that of the wheel. In *Mining*, an intrusion of matter into fissures of rocks, as when a mass of unstratified rocks appears to be injected into a rent in the stratified rocks.

Cogging. In *Carpentry*, the cutting of a piece of timber so as to leave a projection alike to a cog, and the notching of the upper piece so as to conform to and receive it. Alike to *indenting* or *tabling*.

Colter. The fore iron of a plough that cuts earth or sod.

Compass. In *Geometry*, an instrument for describing circles, measuring figures, etc.

A *pair of Compasses* is superfluous and improper.

Connecting Rod. In *Mechanics*, the connection between a prime and second mover, as between the piston-rod of a steam-engine and the crank of a water-wheel or fly-wheel shaft.

The term *Pitman* is local, and altogether inapplicable.

Contrariwise. Conversely, opposite. *Crossways* is a corruption.

Corridor. A *gallery* or passage in or around a building, connected with various departments, sometimes running within a quadrangle; it may be opened or enclosed. In *Fortifications*, a covert way.

Cyma. A molding in a cornice.

Damasquinerie. Inlaying in metal.

Davit. A short boom fitted to hoist an anchor or boat.

Deals. In *Carpentry*, the pieces of timber into which a log is cut or sawed. Their usual thickness is 3 by 9 ins. and exceeding 6 feet in length.

Improperly restricted to the wood of fir-trees.

Dike. In *Engineering*, an embankment of greater length than breadth, impervious to water, and designed as a wall to a reservoir, a drain, or to resist the tides of a river or sea.

Dingey (*Nautical*). A ship or vessel's small boat.

Dock. In *Marine Architecture*, an enclosure in a harbor or shore of a river for the reception, repair, or security of vessels or timber. It may be wholly or partially enclosed. See *Pier*.

When applied to a single pier or jetty, it is a misapplication.

Dowel. A pin of wood or metal inserted in the edge or face of two boards or pieces, so as to secure them together.

This is very similar to coaking, but is used in a diminutive sense. An illustration of it is had in the manner a cooper secures two or more pieces in the head of a cask.

Draught. A representation by delineation. The depth which a vessel or floating body sinks into water. The act of drawing. A detachment of men from the main body, etc.

Ordinarily written *draft*.

Dutchman. In *Mechanics*, a piece of like material with the structure, let into a slack place, to cover slack or bad work. See *Shim*.

Edgewise. An edge put into a particular direction. Hence *endwise* and *sidewise* have similar significations with reference to an end and a side.

Edgeways is a corruption.

Euphroe. A piece of wood by which the crowfoot of an awning is extended.

Fault. In *Mining*, a break of strata, with displacement, which interrupts operations. Also, fissures traversing the strata.

Felloe, Felloes. The pieces of wood which form the rim of a wheel.

Fetch. Length of a reservoir, pond, etc., along which the wind may blow towards the embankment or dam.

Flange. A projection from an end or from the body of an instrument, or of a part composing it, for the purpose of receiving, confining, or of securing it to a support or to a second piece.

Flier. In Carpentry, a straight line of steps in a stairway.

Frap. To bind together with a rope, as to *frap* a fall, etc.

ɛ. In *Architecture*, the part of the entablature of a column which is between ıitrave and the cornice.

um. The part of a solid next the base, left by the removal of the top or t.

ım, although used by some lexicographers, is erroneous.

ngs. Strips of timber or boards fastened to frames, joists, etc., in order to ›eir faces to the required shape or level.

ing. Putting galets into pointing-mortar or cement.

s. Pieces of stone chipped off by the stroke of a chisel. See *Spall.*

t. A small galley built for speed, having one mast, and from 16 to 20 thwarts ɔrs. A Dutch-constructed brigantine.

In *Mechanics*, the hole through which molten metal is poured into a mold ing. *Geat* and *Gett* are corruptions.

ing. A series of teeth or cogged wheels for transmitting motion. To *gear* a e is to prepare to connect its parts as by an articulation.

'e. To shake so as to produce a sharp, clattering noise, commonly *Jingle.*

The circumference of a tree or piece of timber. *Girth.* The band or strap ɔh a saddle or burden is secured upon the back of an animal, by passing his belly. In *Printing*, the bands of a press.

led. Knotty.

e. To clean a vessel's bottom by burning.

ing. Burning off grass, shells, etc., from a ship's bottom. Synonymous *·eaming.*

:met. A wreath or ring of rope.

›al Ring. A circular *rynd* for the connection of the upper mill-stone to the by which the stone is suspended, so that it may vibrate upon all sides.

ıings. The fore part of the wales of a vessel which encompass her bows, fastened to the stem. *Cat harpings*, ropes which brace in the shrouds of er masts of a vessel.

ing. A term applied to the hull of a vessel when her ends drop below her See *Sagging.*

ing. In *Naval Architecture*, calking with a large maul or beetle.

To press, to crowd, to wedge in. In *Nautical language*, to squeeze tight.

›. A pier; the sides of an opening in a wall.

The projecting beam of a crane from which the pulleys and weight are sus- . A sail in a vessel.

To shift a boom-sail from one tack to another; hence *Jibing*, the shifting ›m.

ng. Washing minerals in a sieve.

on. The timber within a vessel laid upon the middle of the floor timbers, .ctly over the keel. When located on the floors or at the sides, it is termed a ɔr a side keelson.

Slit made by cut of a saw.

'. Large wooden cleats to belay hawsers and ropes to, commonly *Cavil.*

uer. A spirituous solution of *lac.* To varnish with lacquer.

n. Articles sunk in the water with a buoy attached.

ınce. A pulpy, gelatinous fluid washed from the cement of concrete depos- water.

sided. A term expressive of the condition of a vessel or any body when it float or sit upright.

'o. To arrest headway of a vessel, without anchoring or securing her to a tc., as by counterbracing her yards, or stopping her engine.

A trench to conduct water to or from a mill-wheel.

In Nautical language, the perpendicular or … *red to a spar or stay.*

Luf. The fullest part of the bow of a vessel.

Mall. A large double-headed wooden hammer.

Mantle. To expand, to spread. *Mantelpiece.* The shelf over a fireplace in front of a chimney.

Marquetry. Checkered or inlaid work in wood.

Matrass. A chemical vessel with a body alike to an egg, and a tapering neck.

Mattress. A quilted bed; a bed stuffed with hair, moss, etc., and quilted.

Mitred. In *Mechanics*, cut to an angle of 45°, or two pieces joined so as to make a right angle.

Mizzen-mast. The aftermost mast in a three-masted vessel.

Mold. In *Mechanics*, a matrix in which a casting is formed. A number of pieces of vellum or like substance, between which gold and silver are laid for the purpose of being beaten. Thin pieces of materials cut to curves or any required figure. In *Naval Architecture*, pieces of thin board cut to the lines of a vessel's timbers, etc. Fine earth, such as constitutes soil. A substance which forms upon bodies in warm and confined damp air.

This orthography is by analogy, as *gold, sold, old, bold, cold, fold*, etc.

Molding. In *Architecture*, a projection beyond a wall, from a column, wainscot, etc.

Moresque. See *Arabesque.*

Mortise. A hole cut in any material to receive the end or tenon of another piece.

Muck. A mass of dung in a moist state, or of dung and putrefied vegetable matter.

Mullion. A vertical bar dividing the lights in a window; the horizontal are termed *transoms.*

Net. Clear of deductions, as *net* weight.

Newel. An upright post, around which winding stairs turn.

Nigged. Stone hewed with a pick or pointed hammer instead of a chisel.

Ogee. A molding with a concave and convex outline, like to an S. See *Cyma* and *Talon.*

Paillasse. Masonry raised upon a floor. A bed.

Pargeting. In *Architecture*, rough plastering, alike to that upon chimneys.

Parquetry. Inlaying of wood in figures. See *Marquetry.*

Parral. The rope by which a yard is secured to a mast at its centre.

Pawl. The catch which stops, or holds, or falls on to a ratchet wheel.

Peek. The upper or pointed corner of a sail extended by a gaff, or a yard set obliquely to a mast. To *peek* a yard is to point it perpendicularly to a mast.

Pendant. A short rope over the head of a mast for the attachment of tackles thereto; a tackle, etc.

Pennant. A small pointed flag.

Pier. In *Marine Architecture*, a mole or jetty, projecting into a river or sea, to protect vessels from the sea, or for convenience of their lading. See *Dock.*

Erroneously termed a *Dock.*

Pile. In *Engineering*, spars pointed at one end and driven into soil to support superstructure or holdfast. *Spile* is a corruption.

Pipe. In *Mechanics*, a metallic tube. The flue of a fireplace or furnace when constructed of metal; usually of a cylindrical form.

The term or application of *Stack* (which refers solely to masonry) to a metallic pipe is a misapplication.

Piragua. A small vessel with two masts and two boom-sails.

Commonly termed *Perry-augur.*

Pirogue. A canoe formed from a single log, propelled by paddles or by a sail with the aid of an outrigger.

...ing. In *Architecture*, covering with plaster cement or mortar upon walls ... England, termed *laying*, if in one or two coat work; and *pricking up* ... work.

... to receive and support the journal of a shaft.

...ce, without tops.

Poppets. In *Naval Architecture,* pieces of timber set perpendicular to a vess bilge-ways, and extending to her bottom, to support her in launching.

Porch. An arched *vestibule* at the entrance of a building. A vestibule suppoı by columns. A *portico.*

Portico. A gallery near to the ground, the sides being open. A *piazza* enc passed with arches supported by columns, where persons may walk; the roof ı be flat or vaulted.

Pozzuolana. A loose, porous, volcanic substance, composed of silicious, argi ceous, and calcareous earths and iron.

Prize. In *Mechanics,* to raise with a lever. To *pry* and a *pry* are corruptions.

Proa, Flying. A narrow canoe, the outer or lee side being nearly flat. A fraı work, projecting several feet to the windward side, supports a solid bearing, in form of a canoe. Used in the Ladrone Islands.

Purlin. In *Carpentry,* a piece of timber laid horizontal upon the rafters (roof, to support the covering.

Ramp. In *Architecture,* a flight of steps on a line tangential to the steps. concave sweep connecting a higher and lower portion of a railing, wall, etc. sloping line of a surface, as an inclined platform.

Rarefaction. The act or process of distending bodies, by separating their pı and rendering them more rare or porous. It is opposed to *Condensation.*

Rebate. In *Mechanics,* to pare down an edge of a board or a plate for the purp of receiving another board or plate by lapping. To lap and unite edges of boa and plates. In *Naval Architecture,* the grooves in the side of the keel for receiv the garboard strake of plank.

Commonly written *Rabbet.*

Remou. Eddy water without progressive action, in bed of a river; a return water against direction of flow of a river.

Rendering. In *Architecture,* laying plaster or mortar upon mortar or wa *Rendered* and *Set* refers to two coats or layers, and *Rendered, Floated,* and *Set* three coats or layers.

Reniform. Kidney-shaped.

Resin. The residuum of the distillation of turpentine. *Rosin* is a corruption.

Riband. In *Naval Architecture,* a long, narrow, flexible piece of timber.

Rimer. A bit or boring tool for making a tapering hole. In *Mechanics,* to *R* is to bevel out a hole. *Riming.* The opening of the seams between the planks vessel for the purpose of calking them.

Rotary. Turning upon an axis, as a wheel.

Rynd. The metallic collar in the upper mill-stone by which it is connecte the spindle.

Sagging. A term applied to the hull of a vessel when her centre drops below ends. The converse of *Hogging.*

Scallop. To mark or cut an edge into segments of circles.

Scarcement. A set back in the face of a wall or in a bank of earth. A footin

Scarf. To join; to piece; to unite two pieces of timber at their ends by runı the end of one over and upon the other, and bolting or securing them together.

Scend. The settling of a vessel below the level of her keel.

Selvagee. A strap made of rope-yarns, without being twisted or laid up, and tained in form by knotting it at intervals.

Sennit. Braided cordage.

Sewage. The matter borne off by a sewer.

Sewed. *In nautical language,* the condition of a vessel aground; she is said t *sewed* by as much as the difference in depth of water around her and her floa depth.

Sewerage. The system of sewers.

Shaky. Cracked or split, or as timber loosely put together.

Shammy. Leather prepared from the skin of a chamois &

Sheer. In *Naval Architecture*, the curve or bend of a ship's deck or sides. *Skeer*, to slip or move aside.

Sheers. Elevated spars connected at the upper ends, and used to elevate h bodies, as masts, etc.

Shim. In *Naval Architecture*, a piece of wood or iron let into a slack place frame, plank, or plate to fill out to a fair surface or line.

Shoal. A great multitude; a crowd; a multitude of fish.

School is a corruption.

Shoar. An oblique brace, the upper end resting against the substance to be ported.

Sholes. Pieces of plank under the heels of shoars, etc.

Shoot. A passage-way on the side of a steep hill, down which wood, coal, etc. thrown or slid. The artificial or natural contraction of a river. A young pig

Sidewise. See *Edgewise.*

Signalled. Communicated by signals.

Signalized, when applied to signals, is a misapplication of words.

Sill. A piece of timber upon which a building rests; the horizontal piece of ber or stone at the bottom of a framed case.

Siphon. A curved tube or pipe designed to draw fluids out of vessels.

Skeg. The extreme after-part of the keel of a vessel; the portion that supp the rudder-post.

Slantwise. Oblique; not perpendicular.

Sleek. To make smooth. Refuse; small coal.

Sleeker. A spherical-shaped, curved, or plane-surfaced instrument with whic smooth surfaces.

Slue. The turning of a substance upon an axis within its figure.

Snying. A term applied to planks when their edges at their ends are curve rounded upward, as a strake at the ends of a full-modelled vessel.

Spall. A piece of stone, etc., chipped off by the stroke of a hammer or the f of a blow. *Spalling*, breaking up of ore into small pieces.

Spandrel. In *Architecture*, the irregular triangular space between the outer l or extrados of an arch, a horizontal line drawn from its apex, and a vertical from its springing.

Sponson. An addition to the outer side of the hull of a steam vessel, commen near the light water-line and running up to the wheel guards; applied for the p pose of shielding the deck-beams from the shock of a sea.

Sponson-sided. The hull of a vessel is so termed when her frames have the line of a sponson, and the space afforded by the curvature is included in the hol

Sponding, *Sponsing*, etc., are corruptions.

Squilgee. A wooden instrument, alike to a hoe, its edge faced with leathe vulcanized rubber, used to facilitate the drying of wet floors, or decks of a vess

Stack. In *Masonry*, a number of chimneys or pipes standing together. chimney of a blast furnace.

The application of this word to the smoke-pipe of a steam-boiler is wholly erroneous.

Stage. In *Engineering*, the interval or distance between two elevations, in sho ling, throwing, or lifting.

Steeving. The elevation of a vessel's bowsprit, cathead, etc.

Strake. A breadth of plank.

Strut. An oblique brace to support a rafter.

Style. The gnomon of a sun-dial.

Sump. In *Mining*, a pit or well into which water may be led from a mine or w

Surcingle. A belt, band, or girth, which passes over a saddle or blanket horse's back.

Swage. To bear or force down. An instrument having a groove on side for the purpose of giving shape to any piece subjected to it when blow from a hammer.

Syphered. Overlapping the chamfered edge of one plank upon the chamfered edge of another in such a manner that the joint shall be a plane surface.

Talus. In *Architecture*, the slope or batter of a wall, parapet, etc. In *Geology*, a sloping heap of rubble at foot of a cliff.

Template. In *Architecture*, a wooden bearing to receive the end of a girder to distribute its weight.

Templet. A mold cut to an exact section of any piece or structure.

Tenon. The end of a piece of wood, cut into the form of a rectangular prism, designed to be set into a cavity of a like form in another piece, which is termed the *mortise.*

Terring. The earth overlying a quarry.

Tester. The top covering of a bedstead.

Tholes. The pins in the gunwale of a boat which are used as rowlocks.

Thwarts. The athwartship seats in a boat.

Tide-rode. The situation of a vessel at anchor, when she rides in direction of the current instead of the wind.

Tire. The metal hoop that binds the felloes of a wheel.

Tompion. The stopper of a piece of ordnance. The iron bottom to which grape-shot are secured.

Treenails. Wooden pins employed to secure the planking of a vessel to the frames.

Trepan. In *Mining*, the instrument used in the comminution of rock in earth-boring at great depths.

Trestle. The frame of a table; a movable form of support. In *Mast-making*, two pieces of timber set horizontally upon opposite sides of a mast-head.

Trice. In *Seamanship*, to haul or tie up by means of a rope or tricing-line.

Tue-iron or *Tuyere.* The nozzle of a bellows or blast-pipe in a forge or smelting-furnace.

Vice. In *Mechanics*, a press to hold fast anything to be worked upon.

Voyal. In *Seamanship*, a purchase applied to the weighing of an anchor, leading to a capstan.

Wagon. An open or partially enclosed four-wheeled vehicle, adapted for the transportation of persons, goods, etc.

Wear. In *nautical language*, to put a vessel upon a contrary tack by turning her around stem to the wind.

Weir. A dam across a river or stream to arrest the water; a fence of twigs or stakes in a stream to divert the run of fish.

Whipple-tree. The bar to which the traces of harness are fastened.

Wind-rode. The situation of a vessel at anchor, when she rides in direction of the wind instead of the current.

Windrow. A row or line of hay, etc., raked together.

Withe. An instrument fitted to the end of a boom or mast, with a ring, through which a boom is rigged out or mast set up.

Woold. To wind; particularly to bind a rope around a spar, etc.

Addenda.

Astragal. In *Architecture*, a round molding, surrounding the head or base of a column. In *Gunnery*, a like molding on cannon near the mouth.

Creosote. An oily colorless liquid, procured from coal-tar.

Flume, a channel for conducting water, as that by which the surplus water of a canal is led to a lower level.

Forebay. The part of a Mill-race or Penstock, from which water flows upon a water-wheel.

Grillage. A frame, constructed of beams laid in parallel row- ight angles, with others notched over them.
Designed to uniformly distribute or extend the area of a fou

Hypotenuse. Commonly, but incorrectly, hypothenuse.

Jetty. In *Naval Architecture*, a pier that juts out or projects into a river or a sea, a landing-place.

Kibble. In *Mining*, a metallic bucket in which ore is drawn up to the surface.

Lewis. One or two frustums of a right-angled metallic wedge, set inverted or dove-tailed and keyed in a wedge-formed slot, in stone or like solid substance, whereby it may be lifted and laid without the use of slings.

Newel. In *Engineering*, a cylindrical pillar terminating a wing wall of a bridge or viaduct.

Parcelled. *Nautical.* Wrapped with canvas or tarred rope, to resist wear from friction.

Payed. *Nautical.* Painted, tarred, or greased, to resist moisture and wear.

Penstock. An artificial conduit for water to a water-wheel, and furnished with a flood-gate.

Ravel. To disentangle, untwist, or unweave.

The usual prefix of *Un* is wholly superfluous.

Roil. To render turbid, to stir or mix.

Scabble. The dressing of the faces of rough stones, as with a broad chisel.

Served, Service. *Nautical.* The layer of wrapping, as spun yarn, lines, etc., around a stay or rope, to resist friction and wear.

Shackle, or Clevis. An open link set in a chain, secured by a pin running through eyes in its ends, which, when withdrawn, admits the chain to be parted at that point.

Soffit. In *Architecture*, the under side of an opening; the lower surface of a vault or arch; also the under surface of an arch between columns.

Splay. In *Architecture*, a sloped surface, or one making an oblique angle with another. A large chamber.

Strike, in *Geology*, is the compass direction of the intersection of the plane of stratified rock with the plane of the horizon.

Altars. In *Naval Architecture*, the steps on the sides and end of a marine dock.

Gin. An instrument operated by men or animals for the raising or drawing of heavy bodies; usually a vertical revolving windlass and lever.

Sump. In *Salt-works*, a pond in which the sea or saline water is retained for use in the future.

Skeet. *Nautical.* A scoop with a long handle, for use in wetting the sails or the sides of a vessel.

Wyes. The vertical standards on which the telescope of a Theodolite or Level is supported, and which admits of their being reversed by a reversal of its ends. When the telescope is reversed by rotation on its trunnions, the instrument is termed a Transit.

THE END.